THE ENGINEER

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THE ENGINEER

Established 1856

No. 5453 **JULY 29, 1960** VOL. 210

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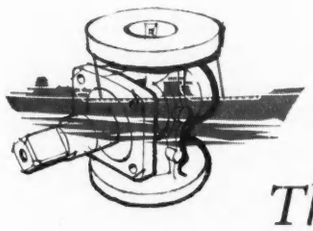

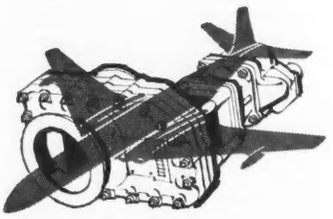

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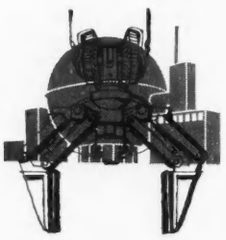

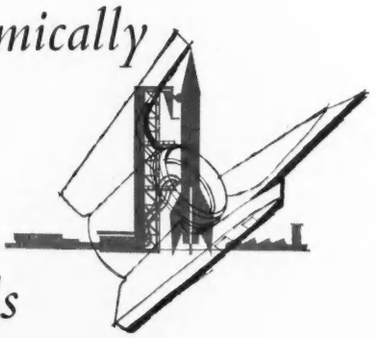

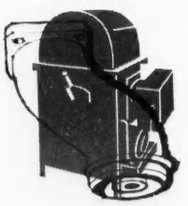

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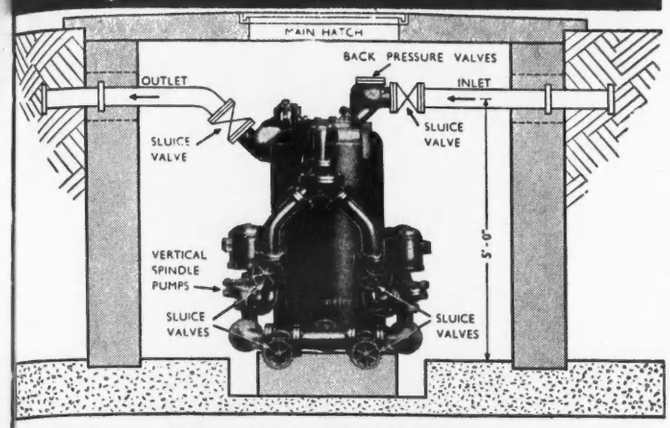

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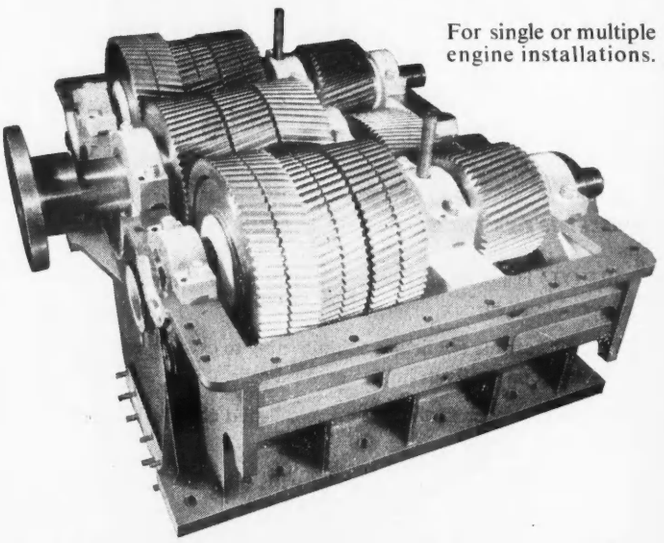

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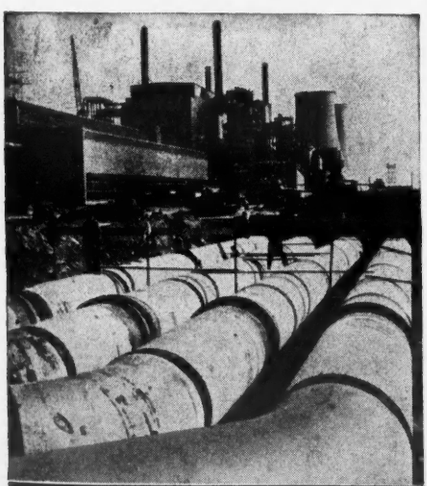

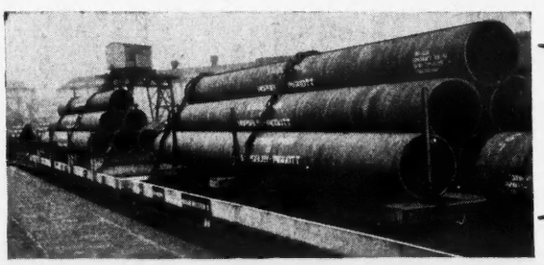

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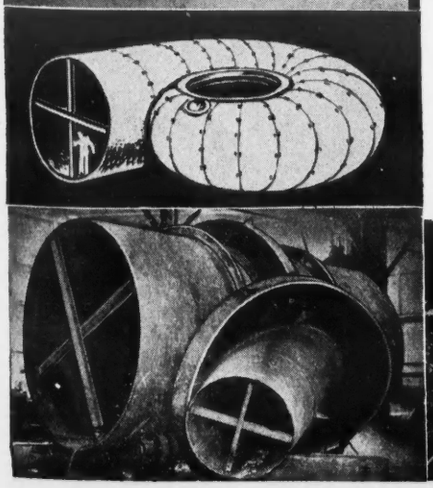

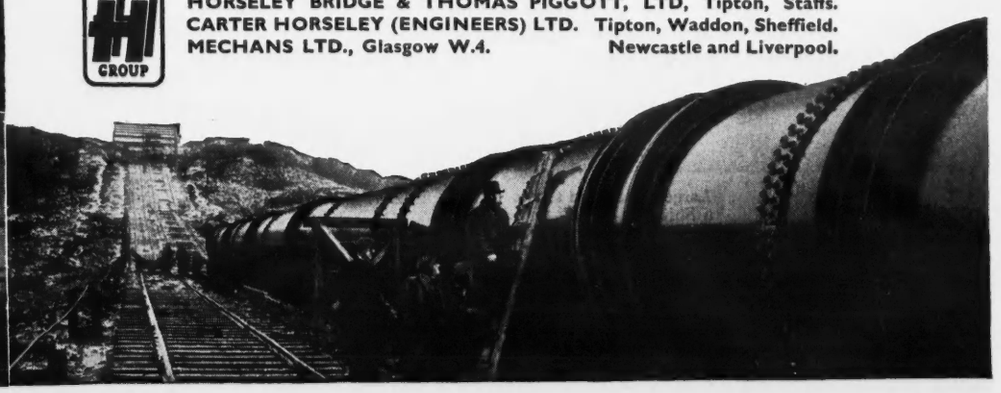

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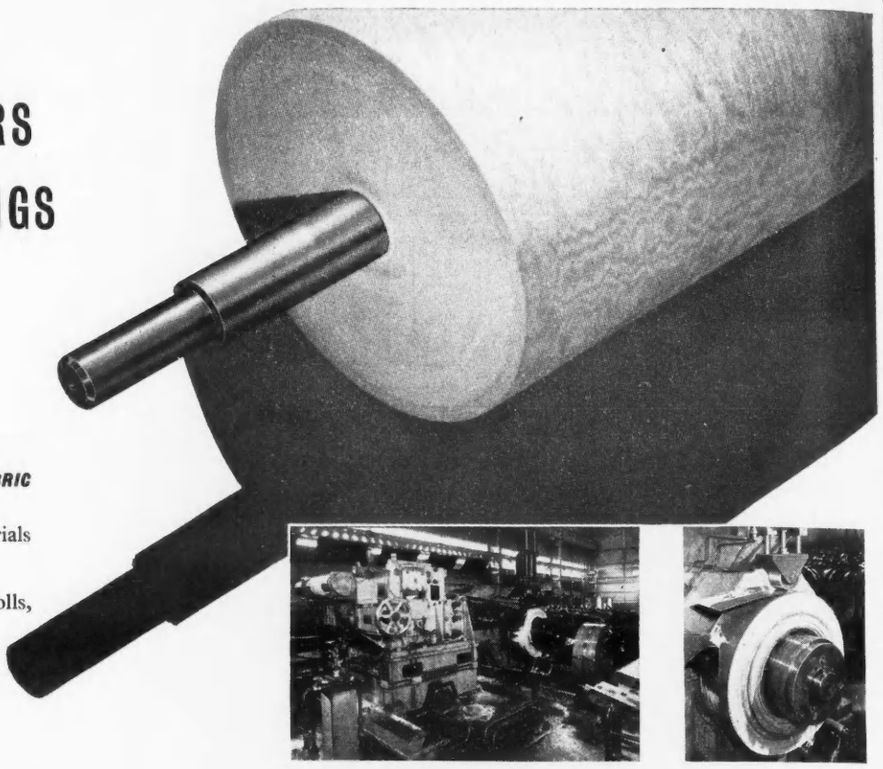

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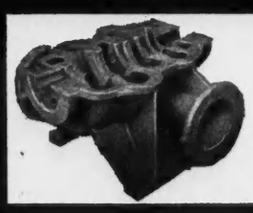

Large illustration shows a Shipham casting for a Centrifugal Pump Cover —overall length 4′ 0″; weight 1330 lbs. Alongside—Centrifugal Pump Body — overall length 4′0″; weight 2425 lbs.

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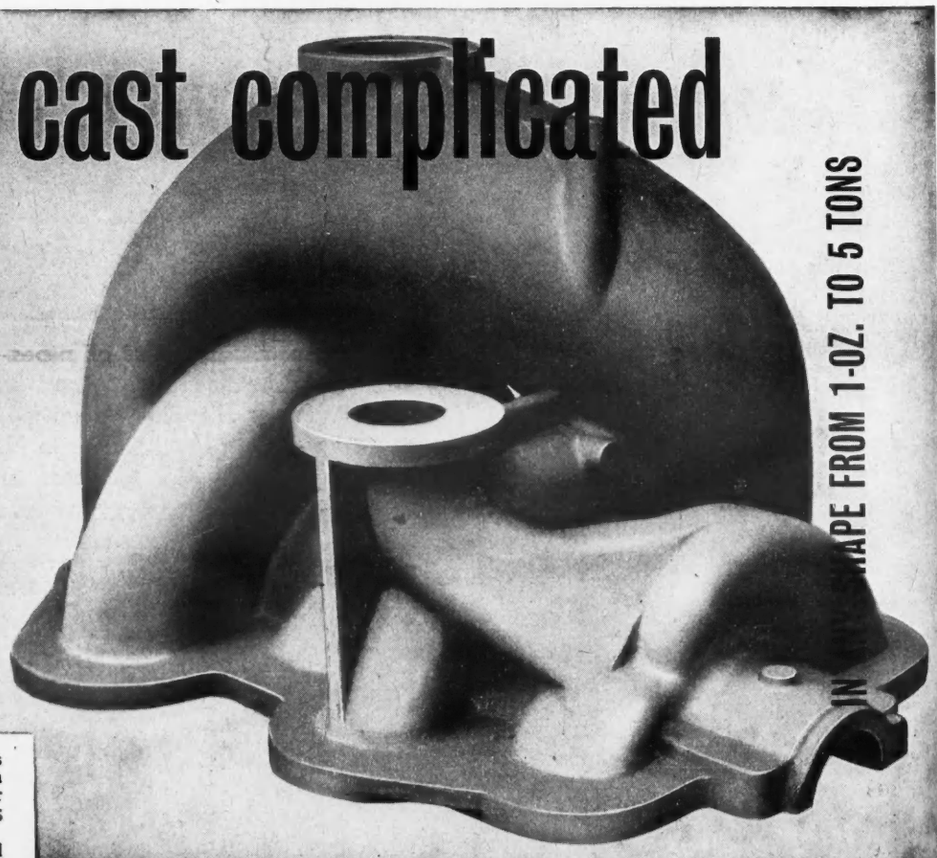

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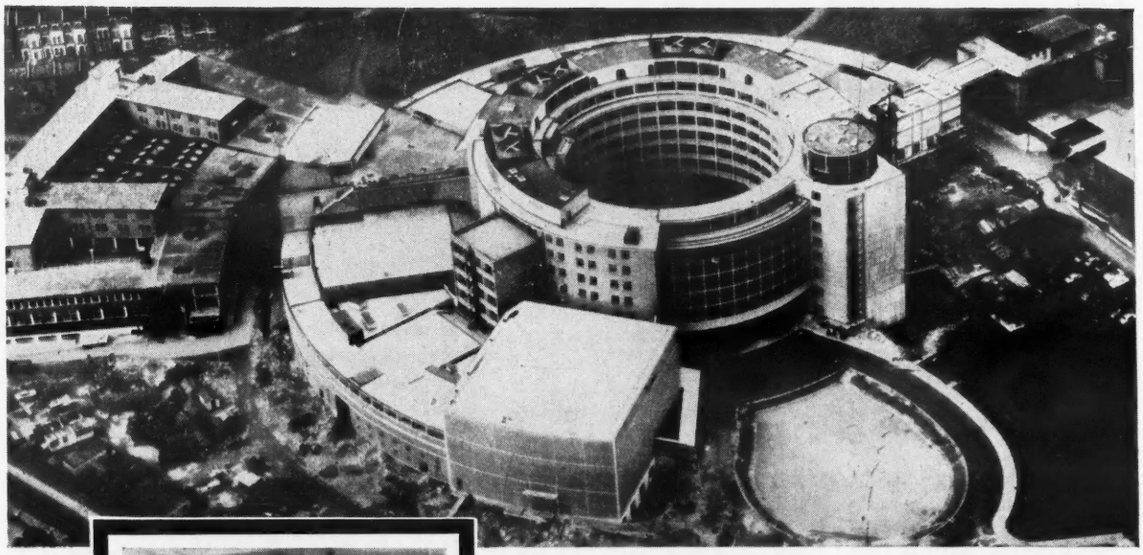

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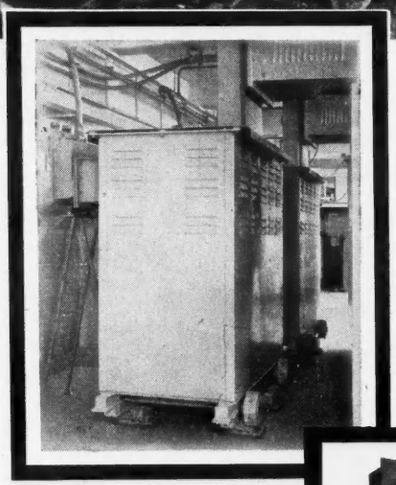
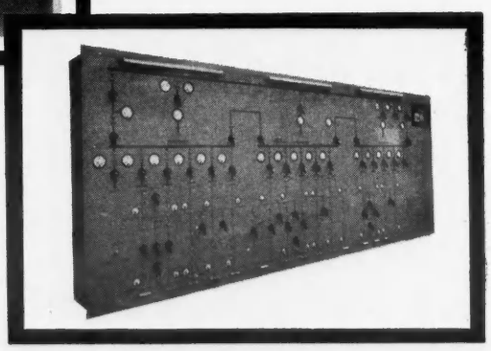


Two of the nine 750-kVA distribution Transformers.

The newly-opened B.B.C. Television Centre at the White City consumes considerable electric power and requires a safe and dependable supply.

Brush Control panels have been chosen for the three control rooms located within the studio area, controlling both 11kV and 415 volt supplies.

Brush have also supplied nine 750-kVA Transformers housed in Substations on the periphery of the new circular building. These dry type Transformers with class 'C' insulation rely on surrounding air as the sole cooling medium and are able to withstand temperatures in excess of 180° C continuously.



Brush Control Panel in the Central Apparatus Room.

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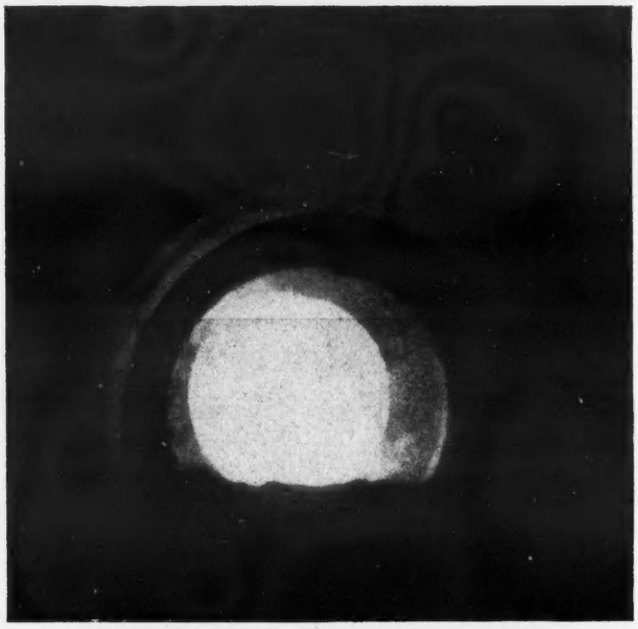

Photograph taken through the sight port of the combustion chamber of an Economic Boiler—approximate fuel ouput 350 lbs. per hour—CO_2 of over 13%—Smoke Number between 1 and 2

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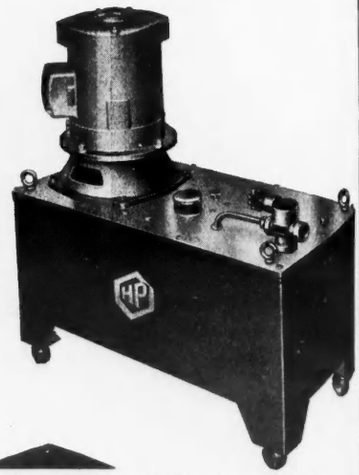

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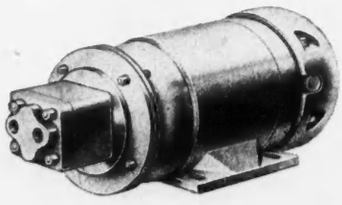

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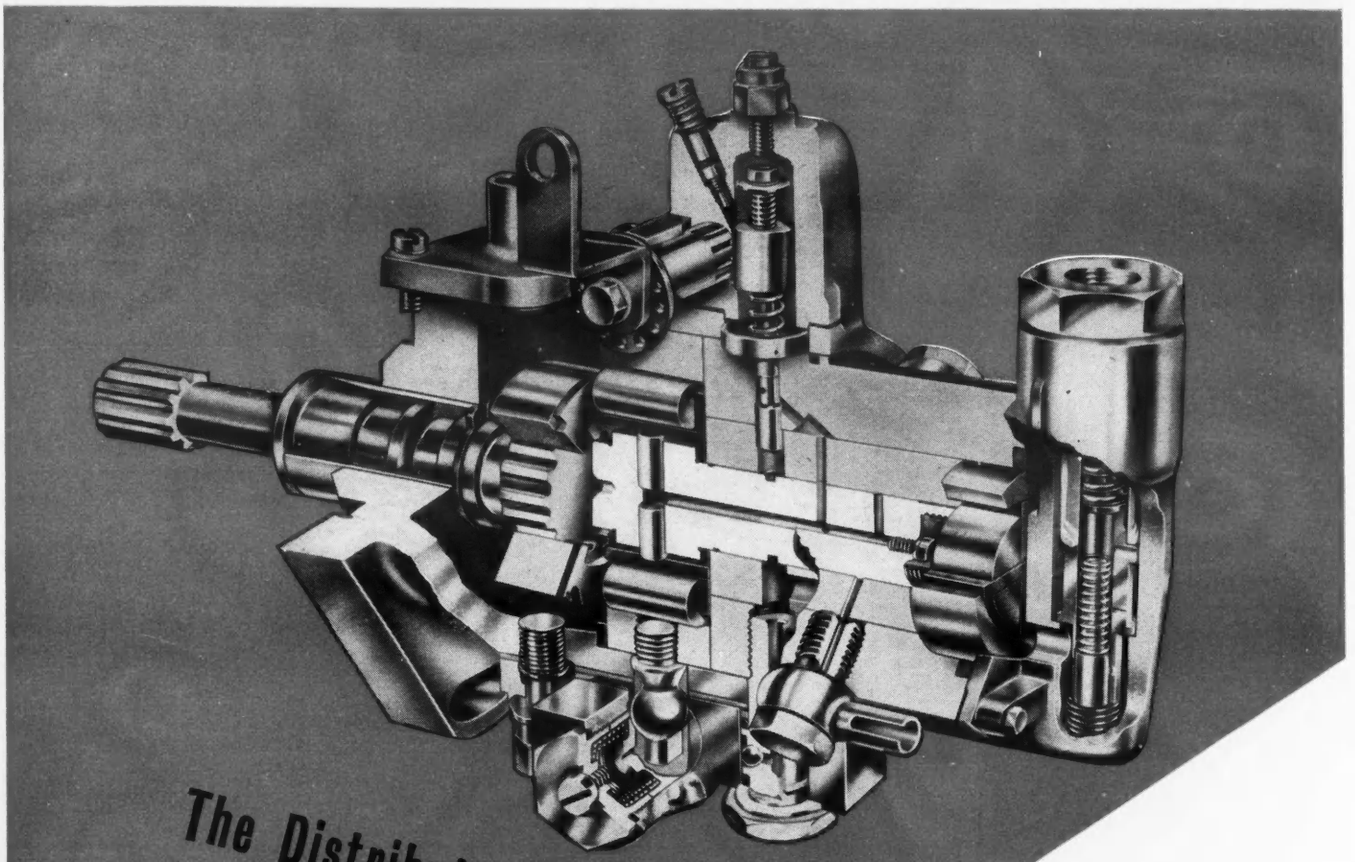
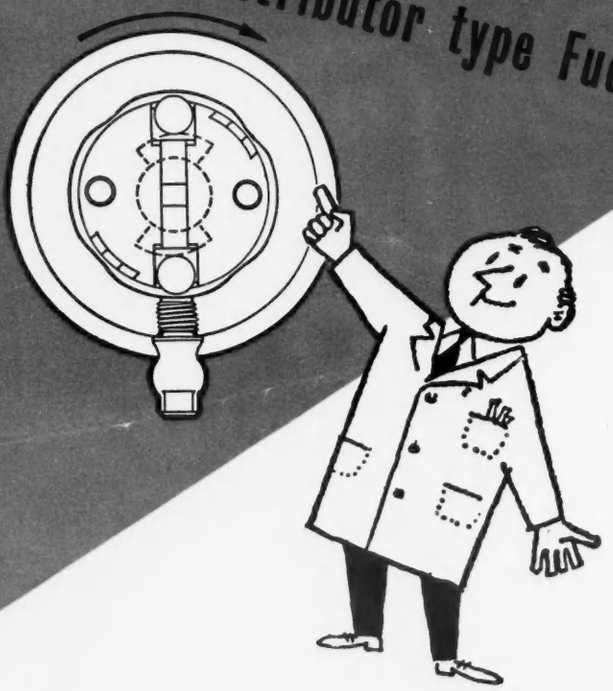


The Distributor type Fuel Injection Pump



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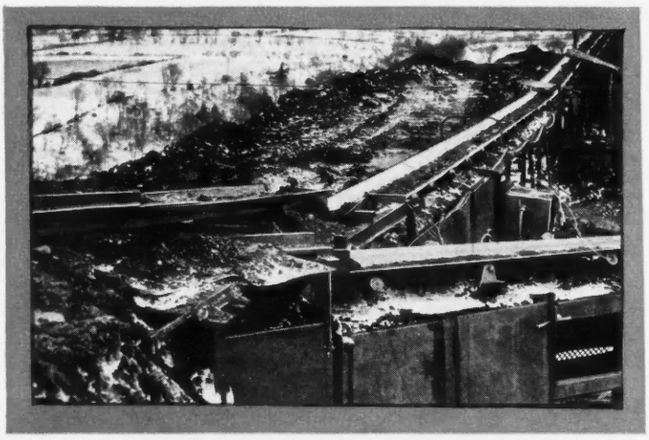

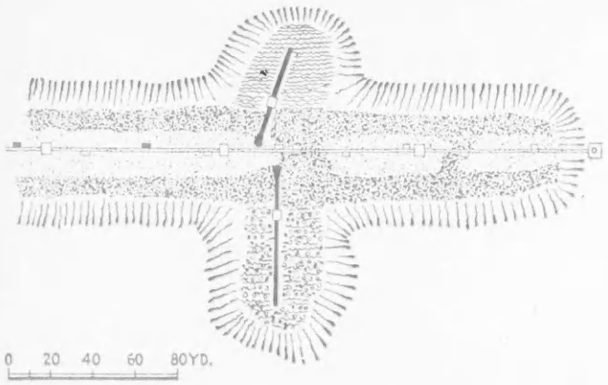

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—more than 1,000,000 tons without repair or overhaul

Waste heaps which have reached their maximum height can be extended laterally in any required direction without shifting aerial ropeways. Duckbills and shaker conveyors have been doing this 'earth-moving' job reliably for many years. Automatic loading below the aerial discharge point, easy extendability, and adaptability to changing terrain have been important advantages of this equipment, which can easily keep pace with normal dumping rates and if need be, work 'round the clock.' This machinery has handled waste with maximum water absorption.

The photographs show a shaker conveyor working in conjunction with two belt conveyors. The diagram shows a scheme in its early stages employing a duckbill and a shaker conveyor alone. With this scheme, the life of the tipping area has been extended by 20 years without movement of or addition to the ropeway.

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Place: LEYLAND MOTORS LIMITED
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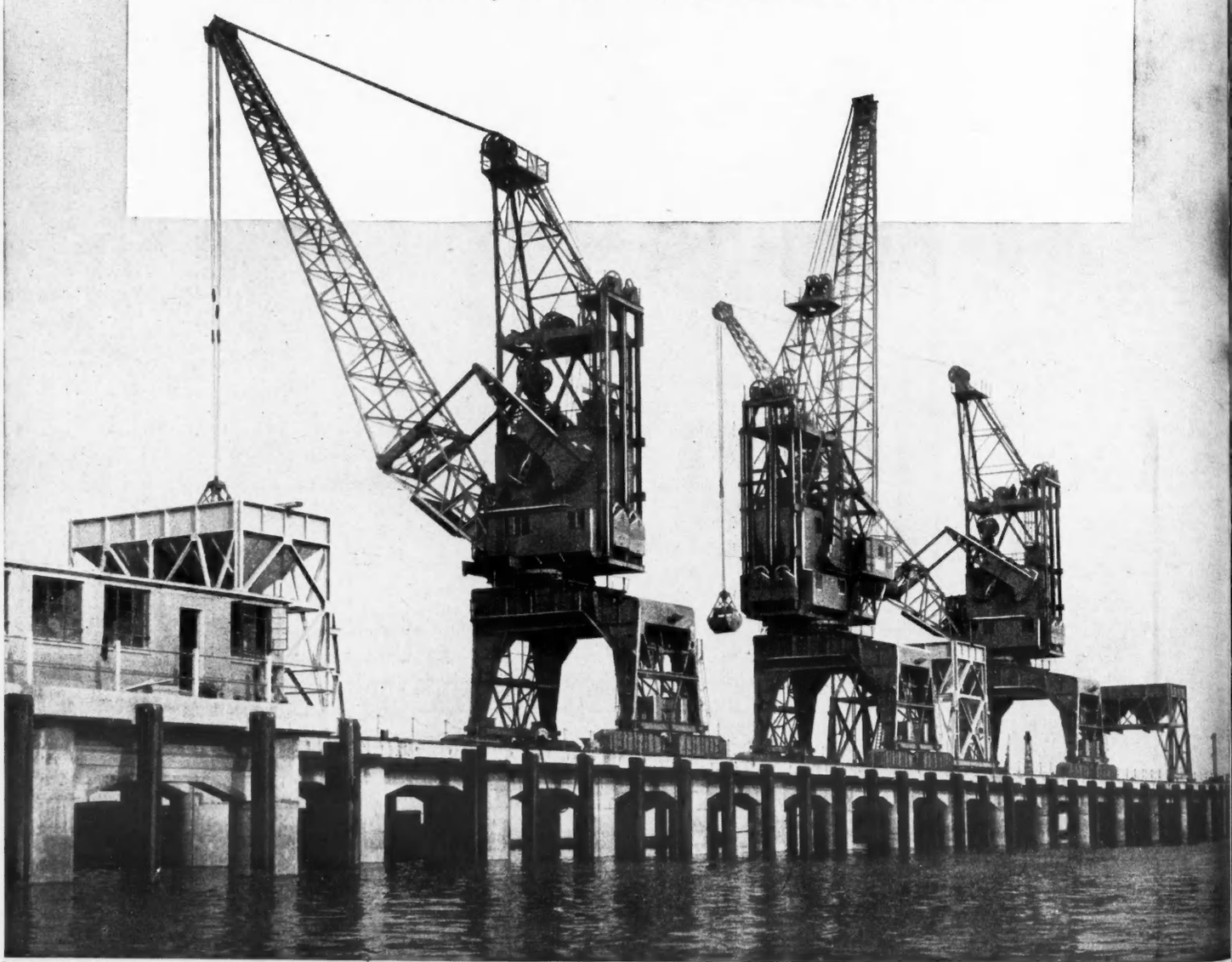

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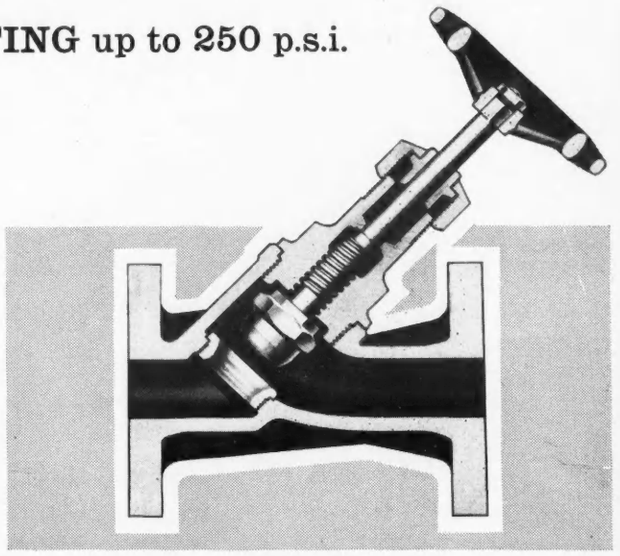

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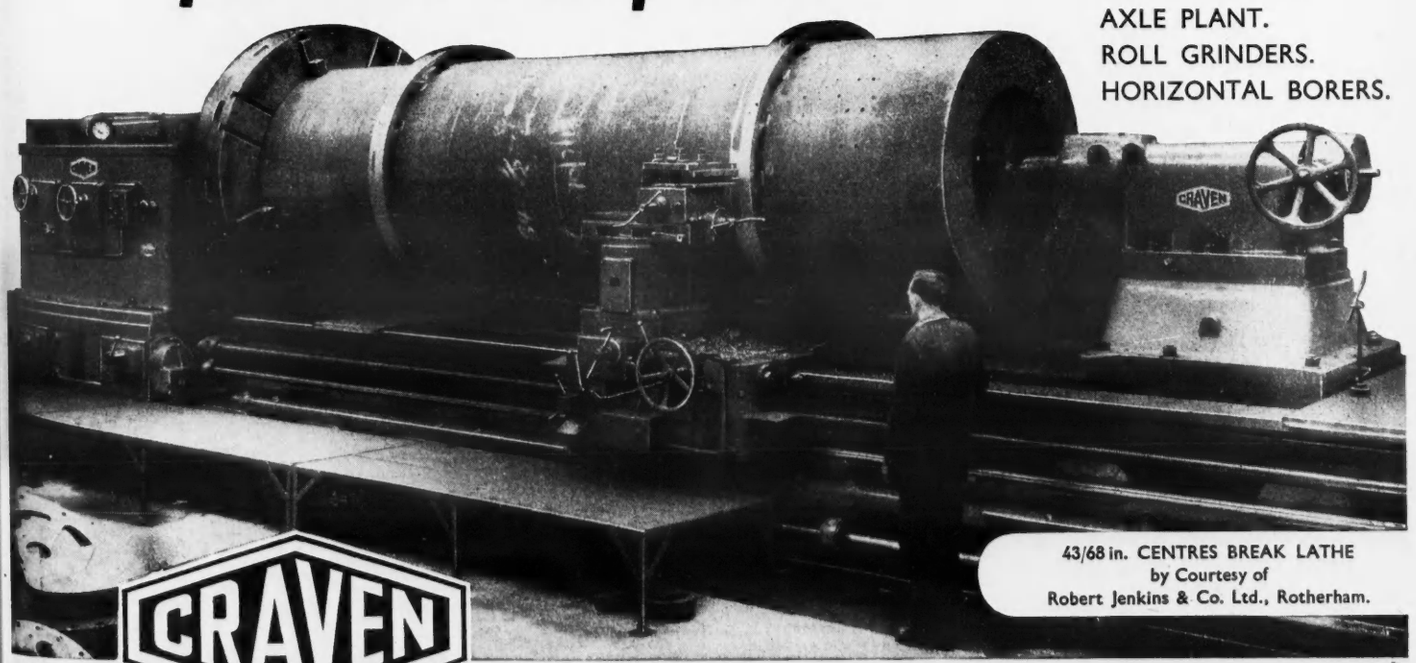

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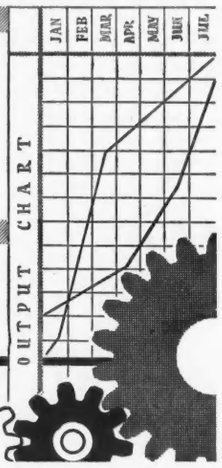

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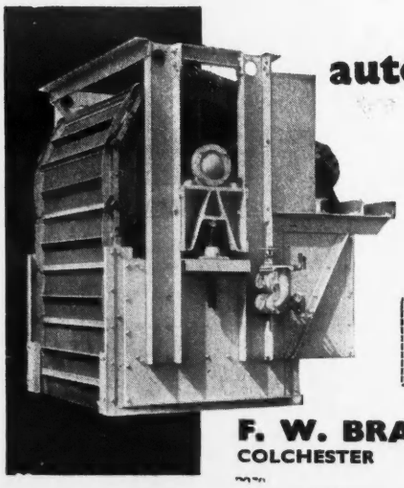

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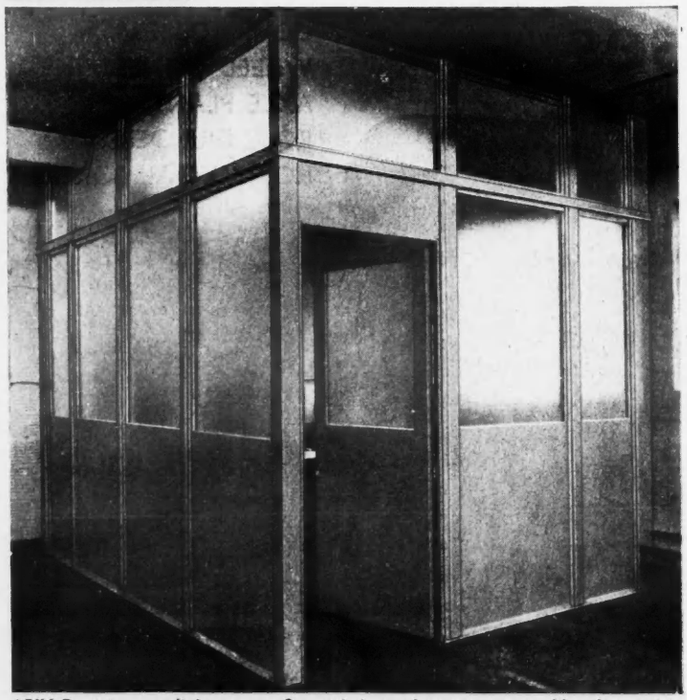

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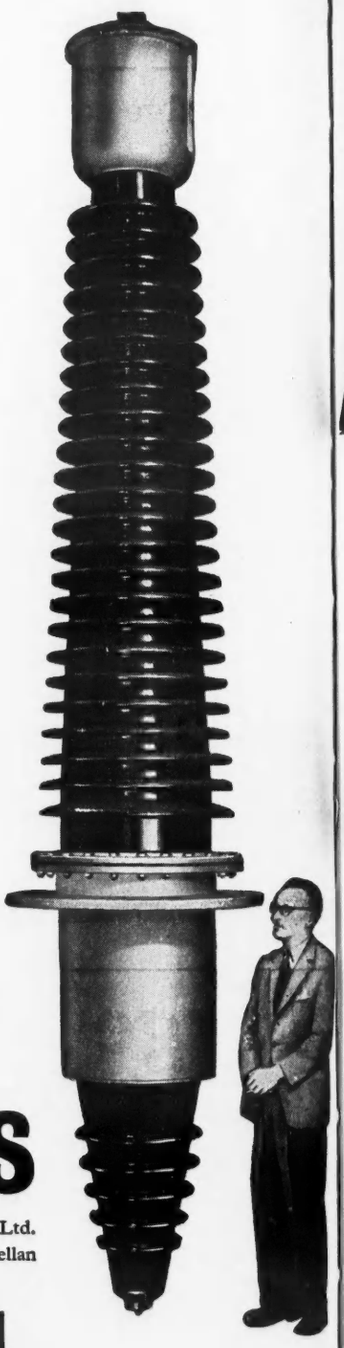
KARIBA at 330 kV.



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All the 330 kV. strain insulators for the substations
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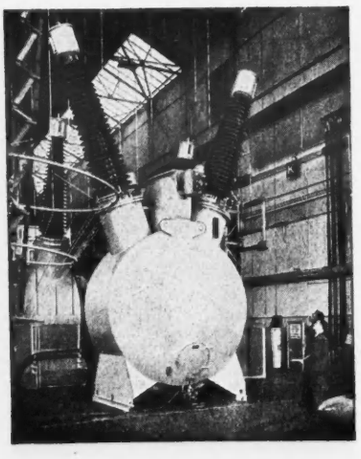

The illustrations show a complete 330 kV. bushing insulator and a 330 kV. circuit breaker, by courtesy of the B.T.H. Co.

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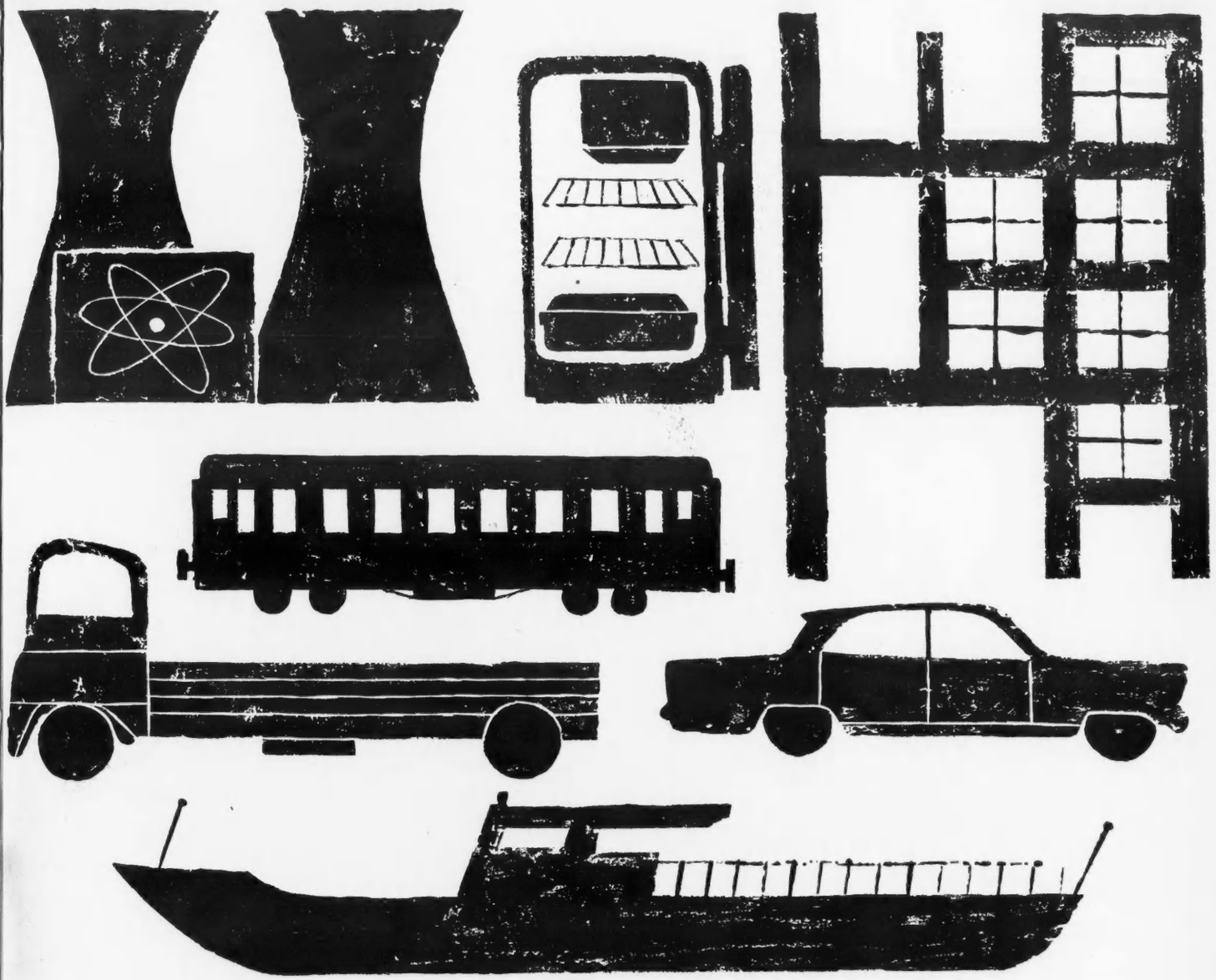

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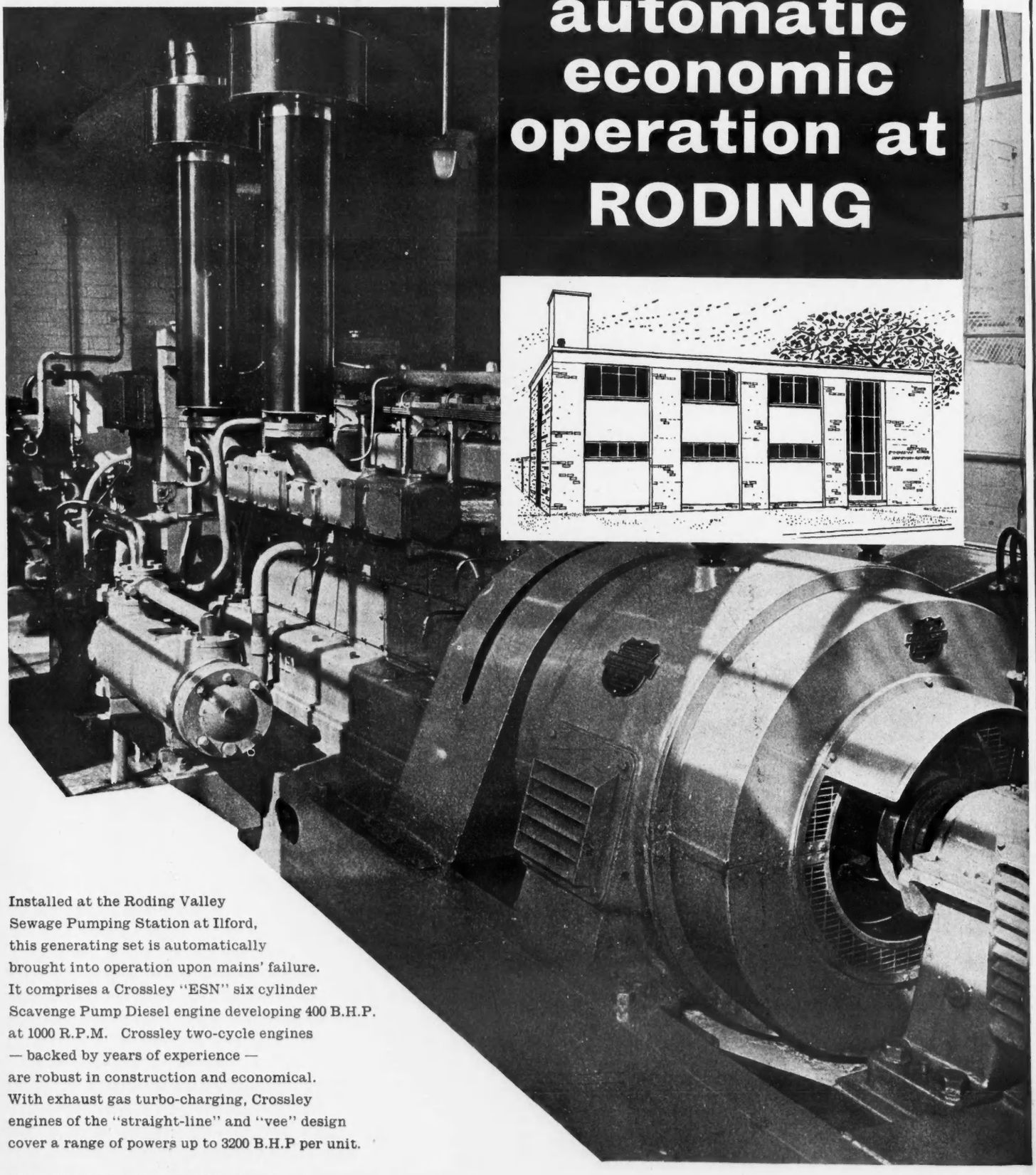

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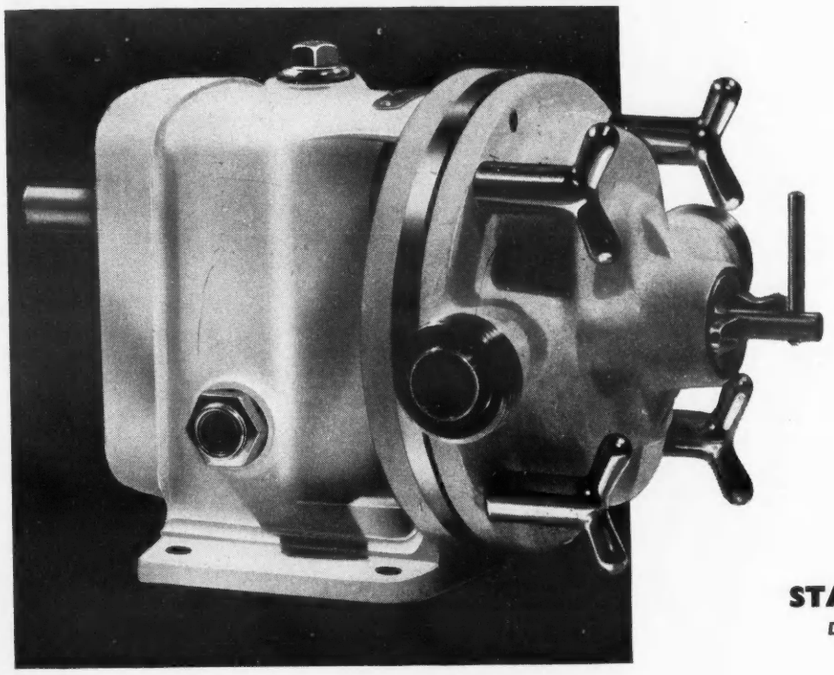

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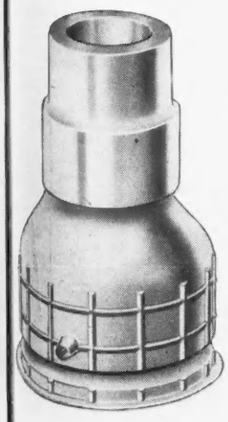

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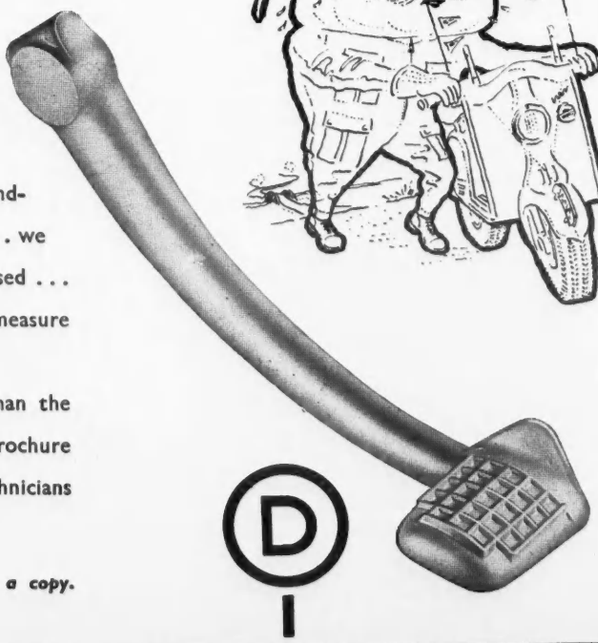

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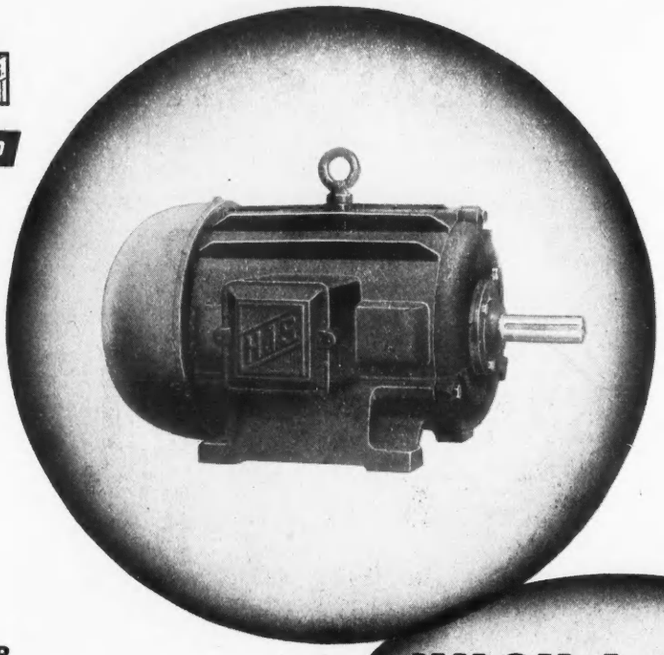

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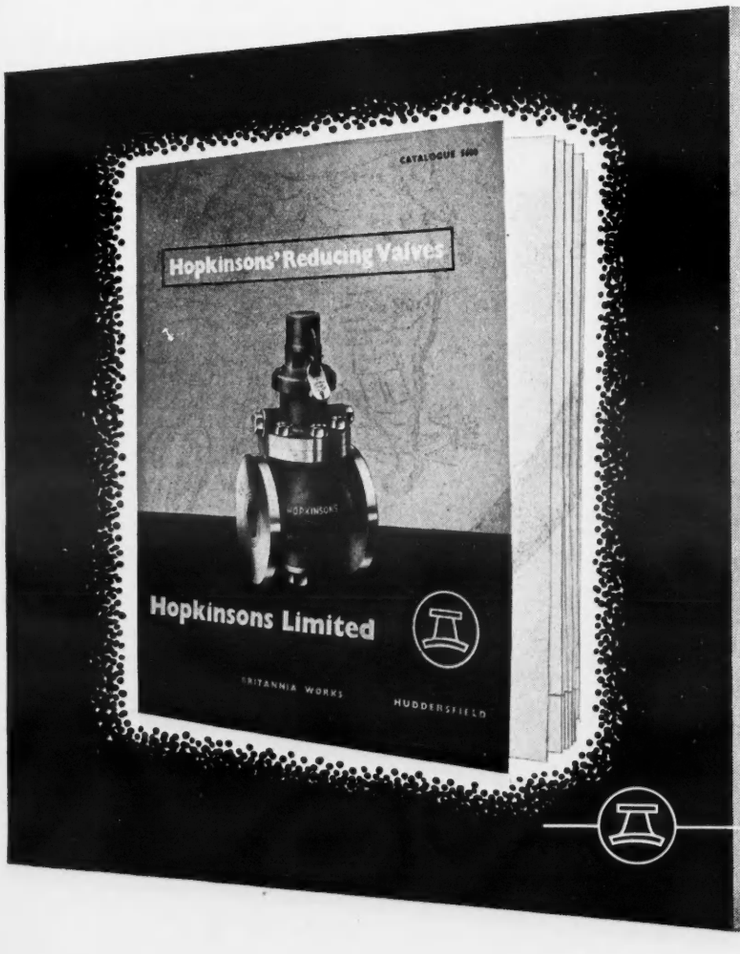

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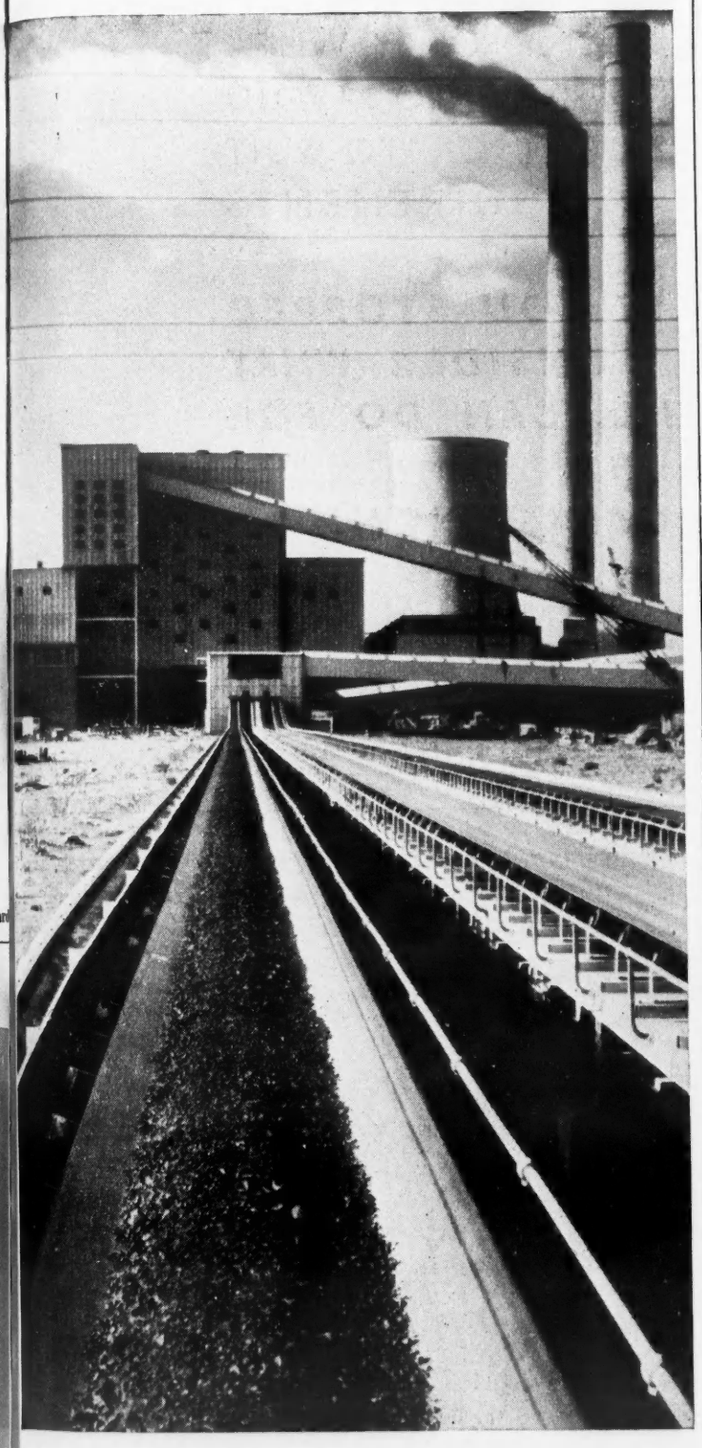

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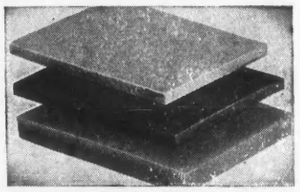

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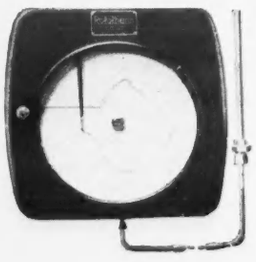

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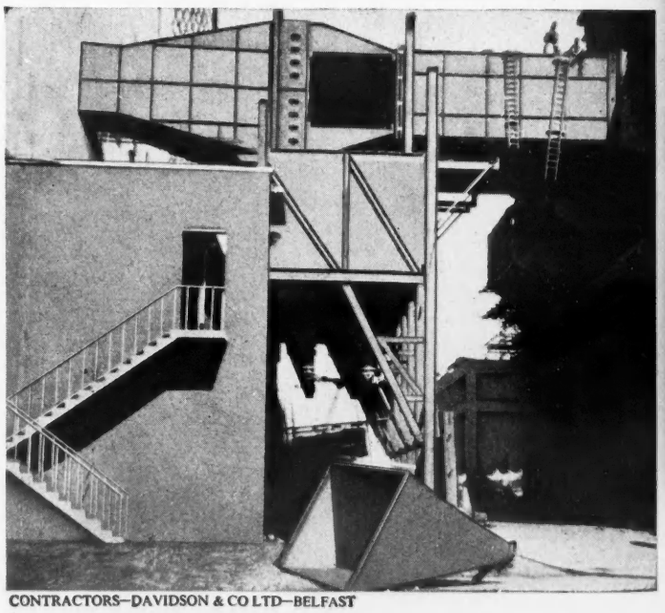

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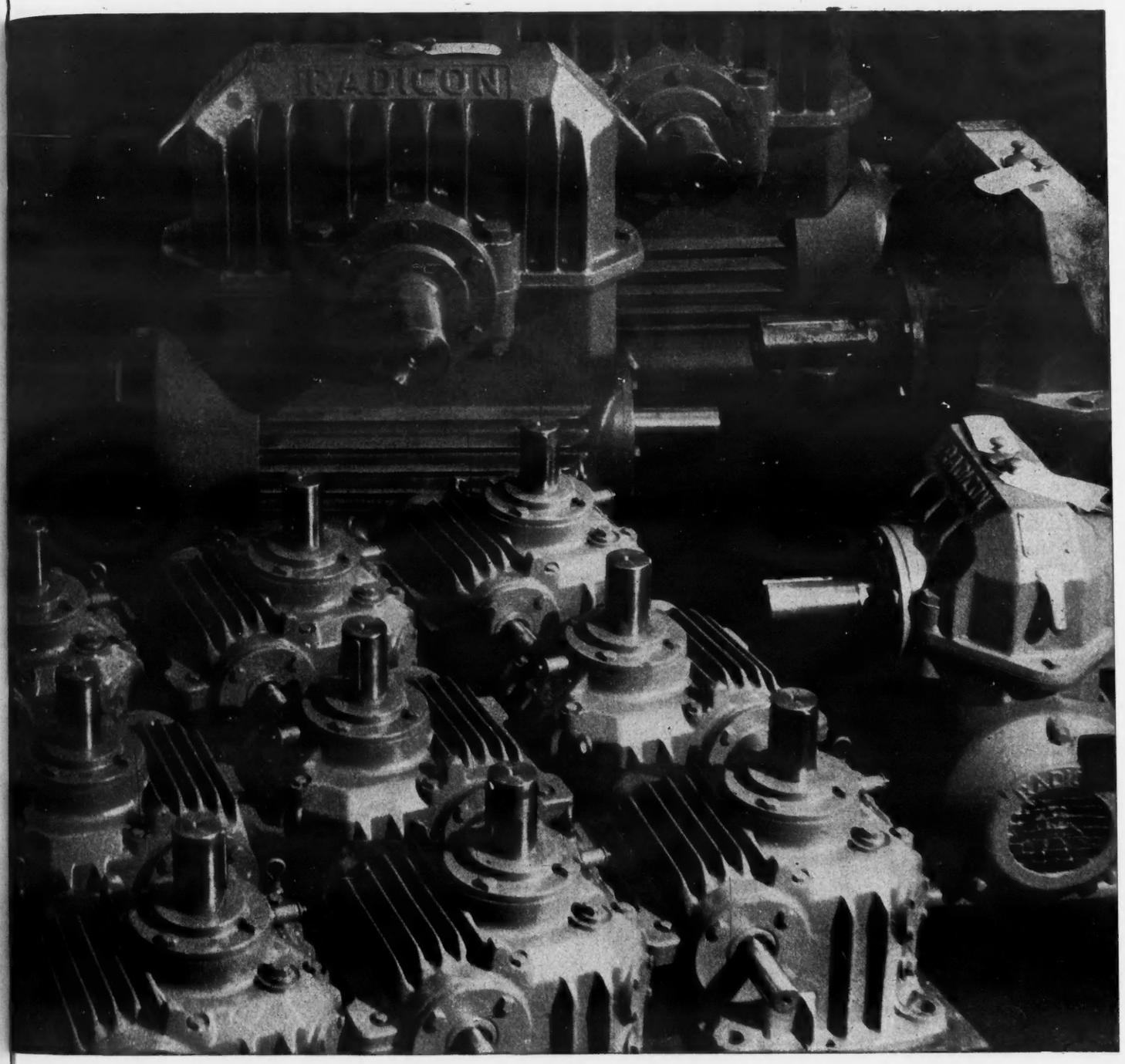

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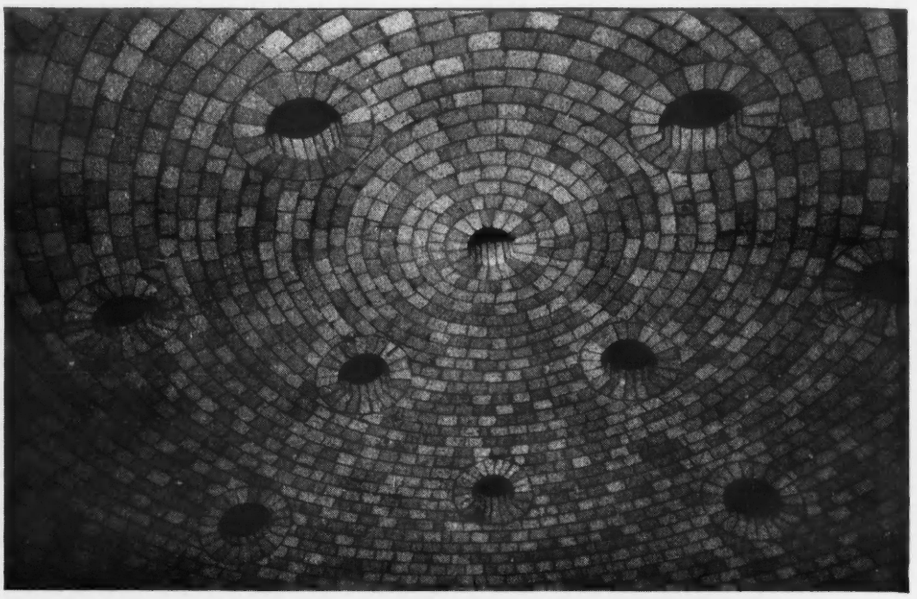

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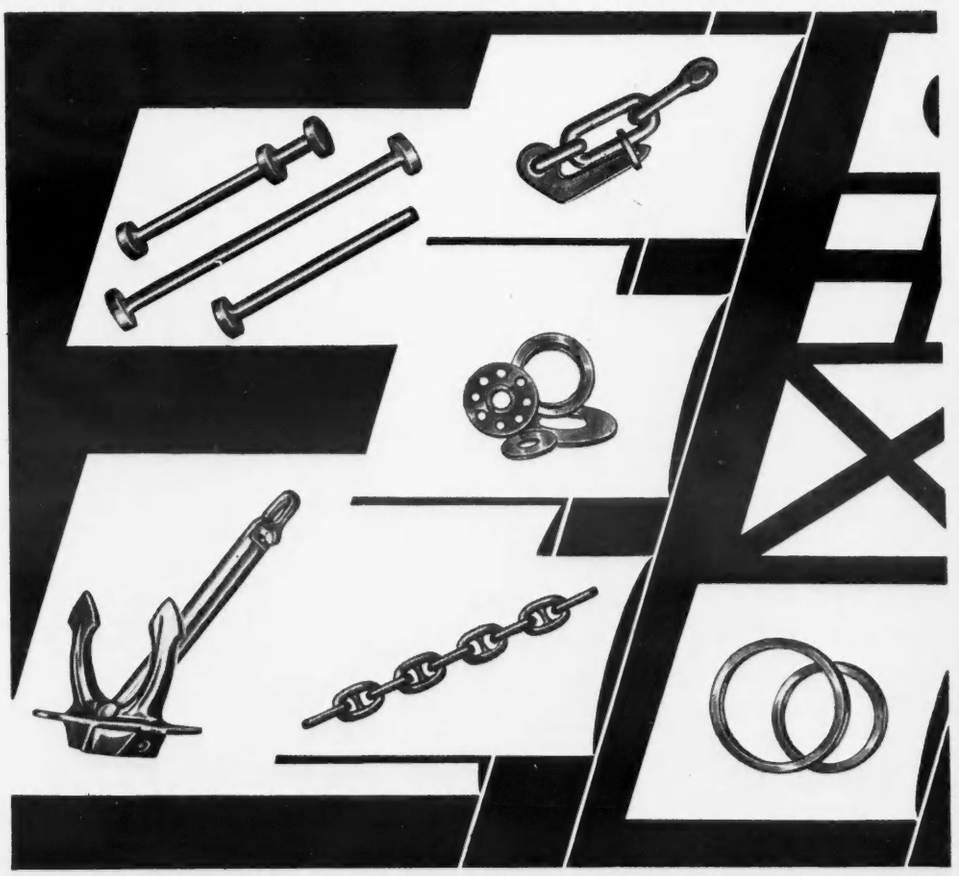

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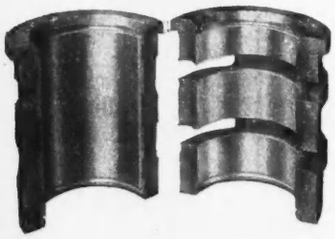

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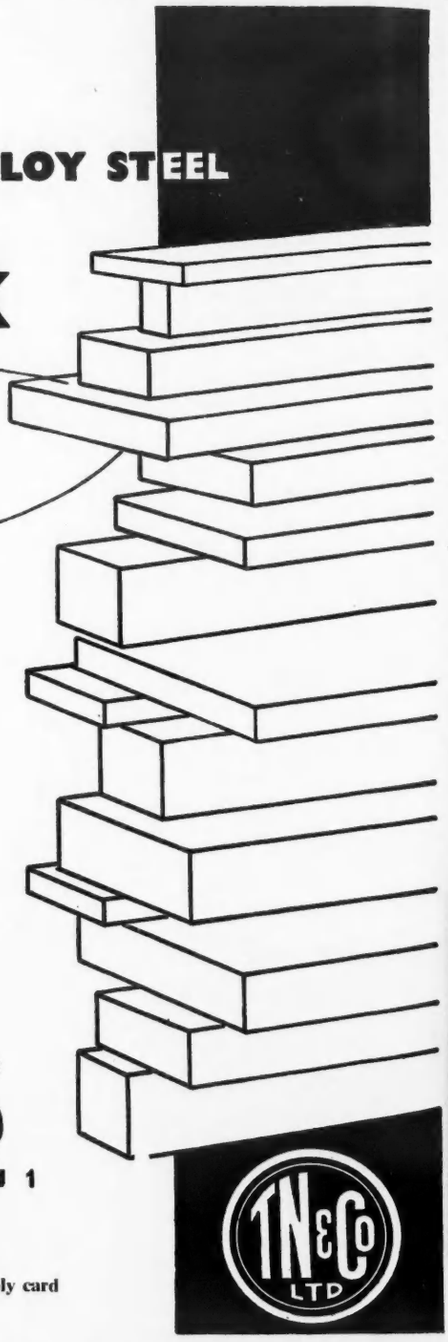

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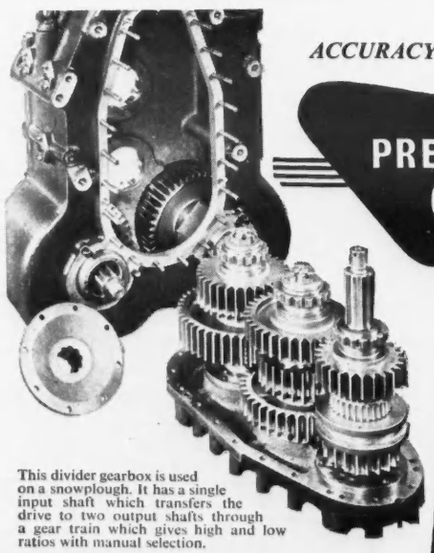

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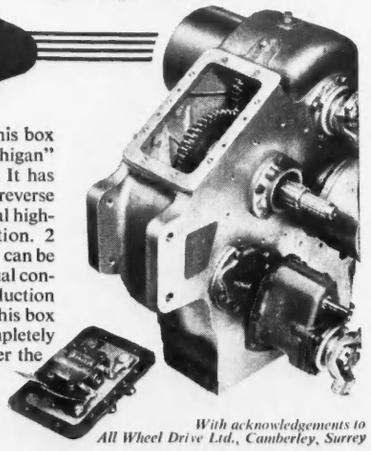

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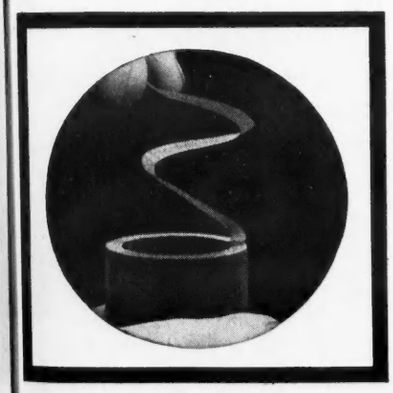

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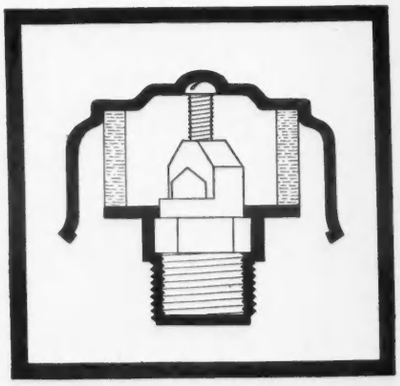

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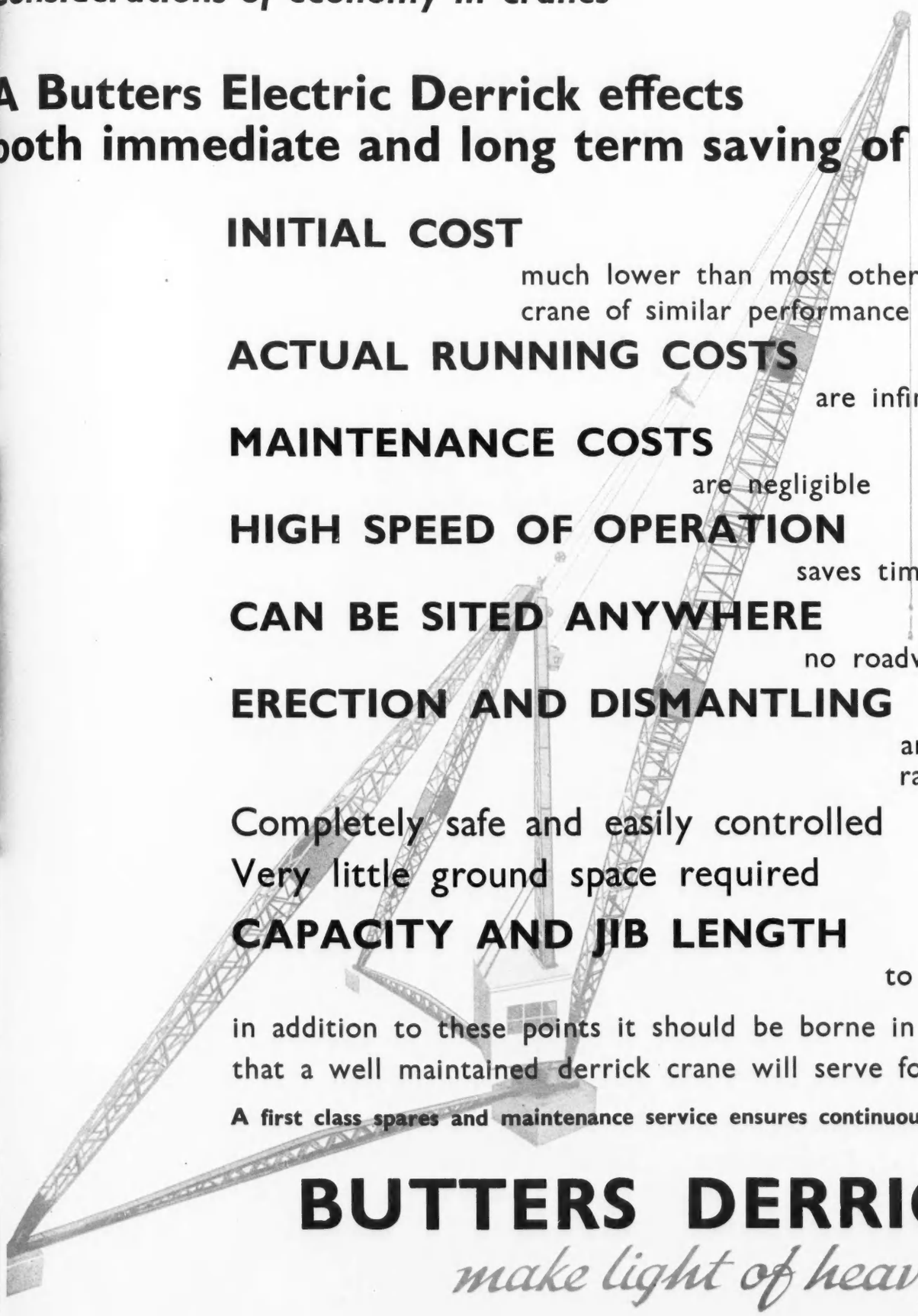

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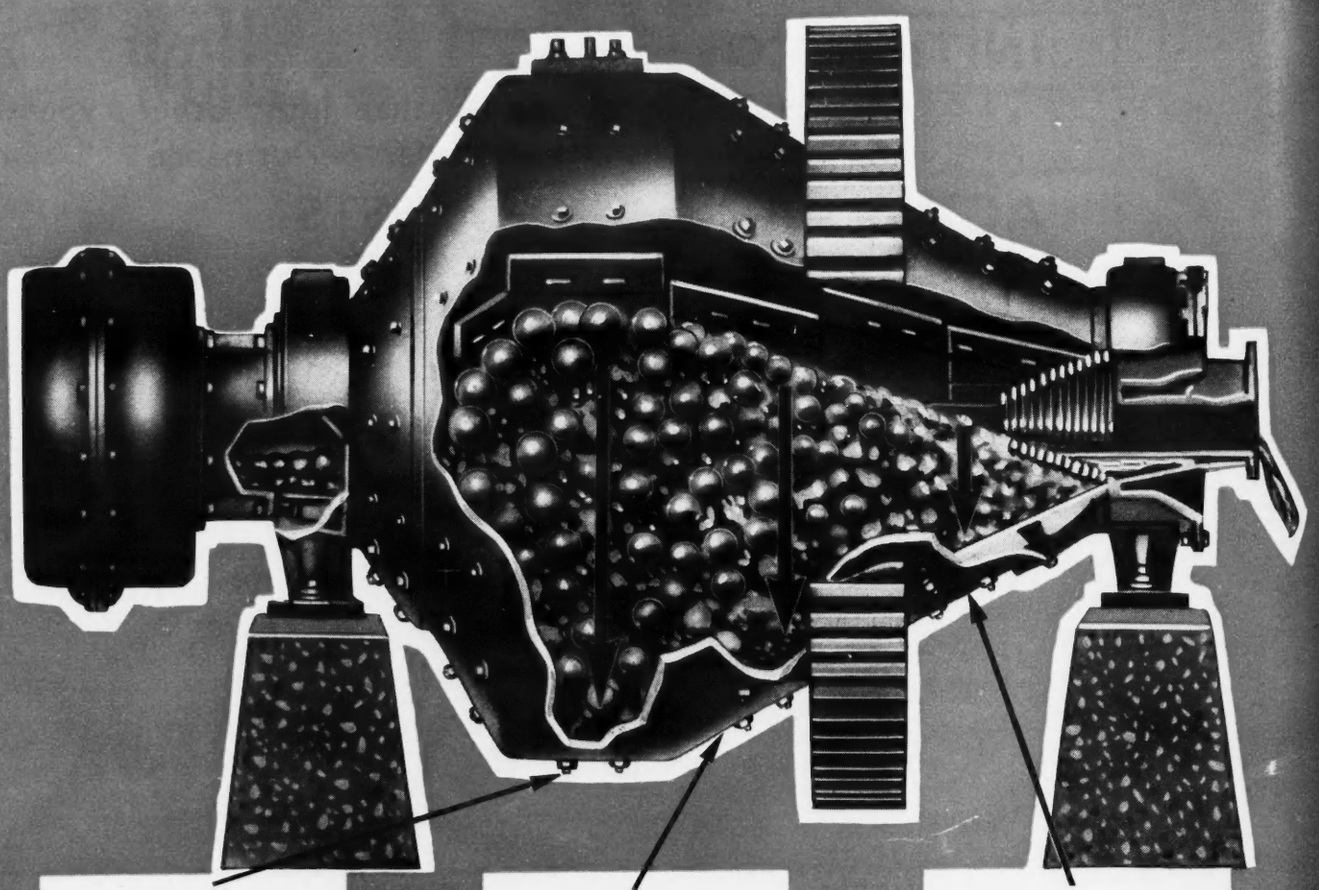

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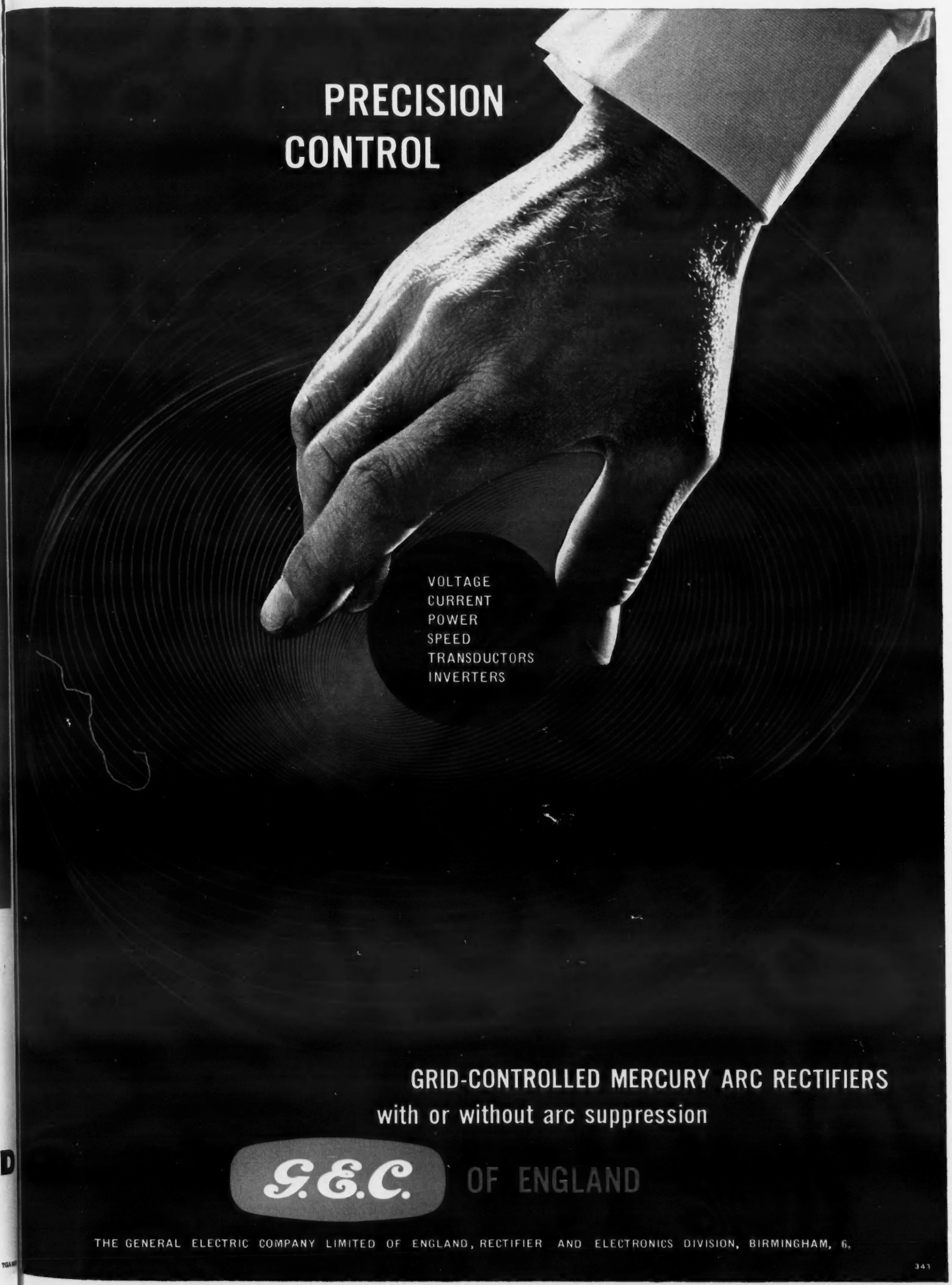

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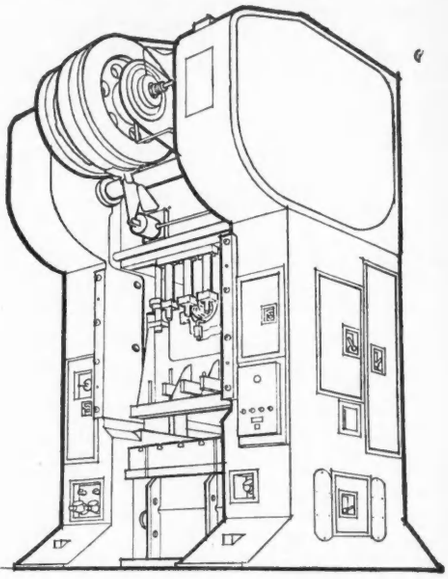

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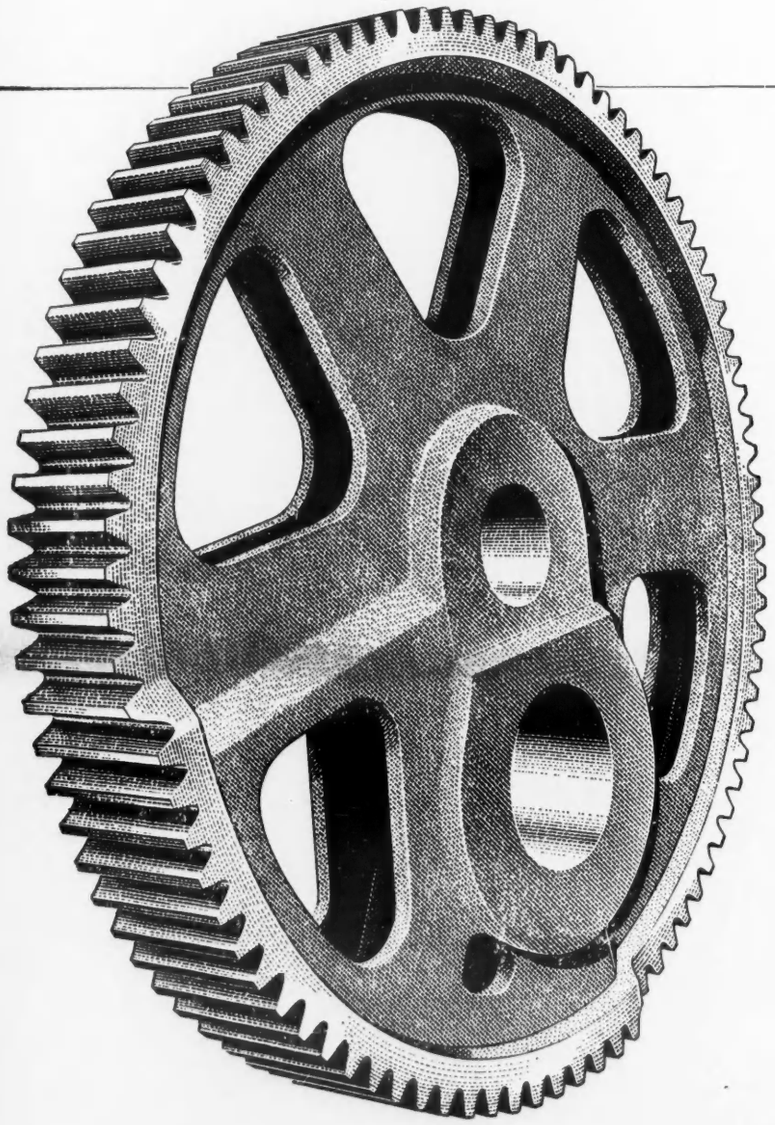

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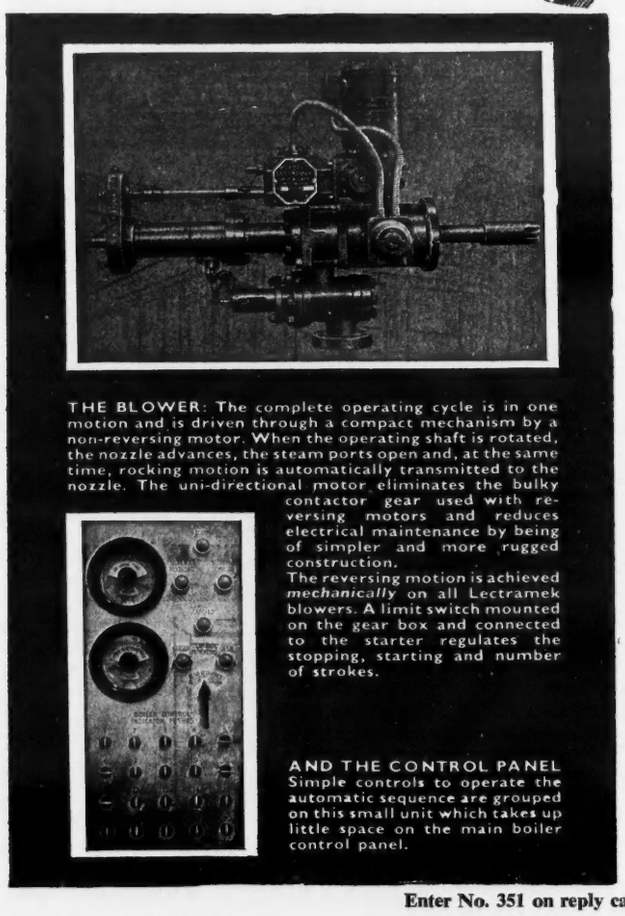

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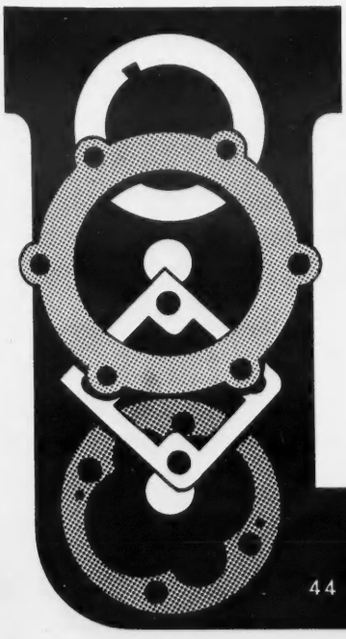

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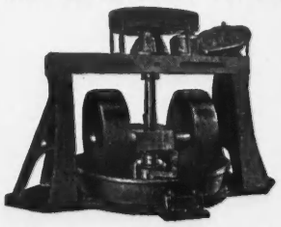

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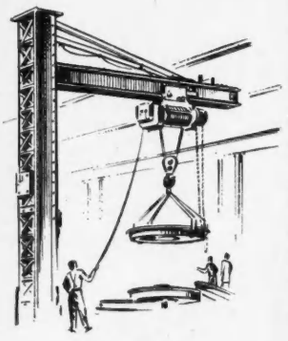

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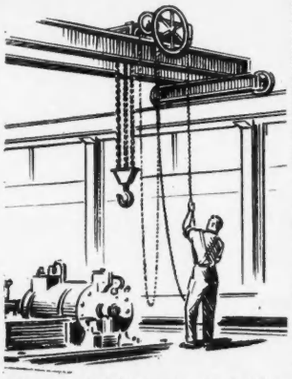

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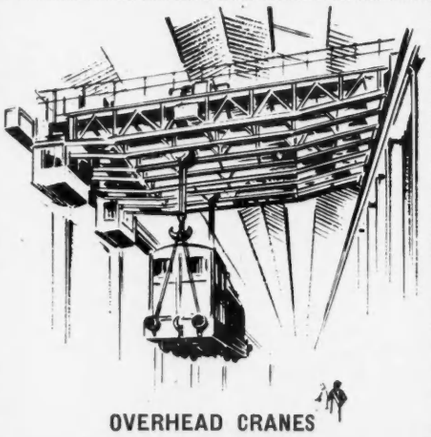

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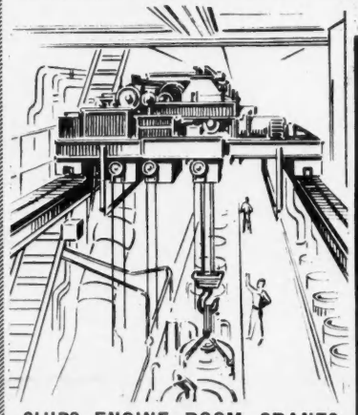

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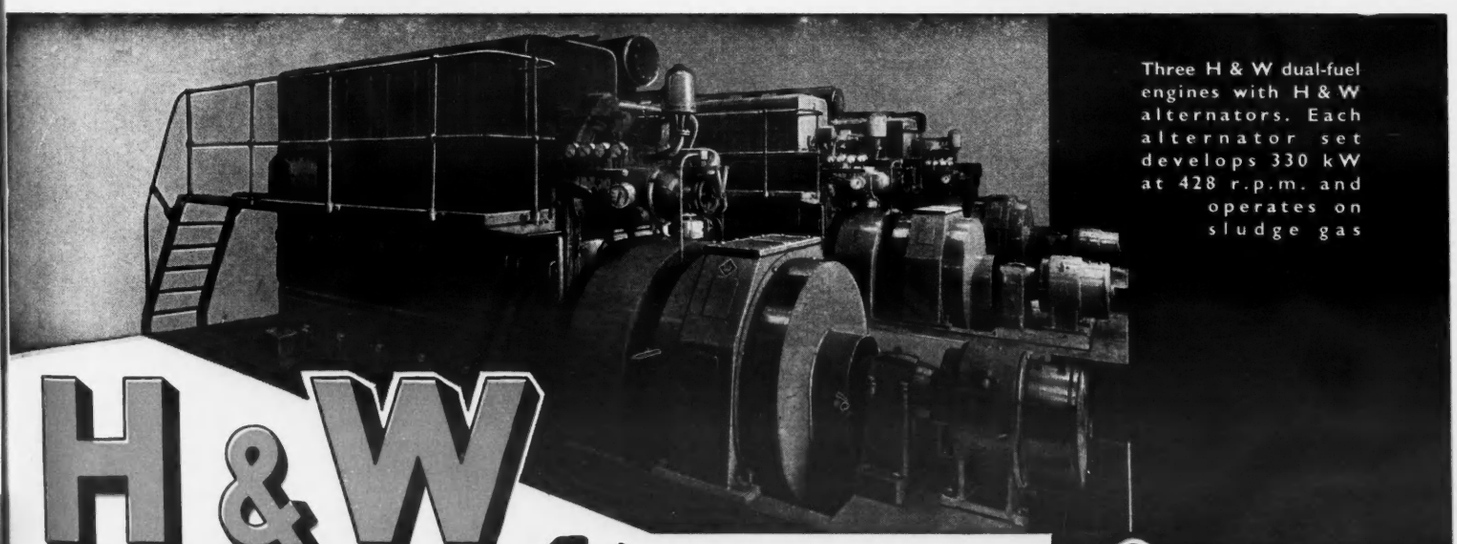
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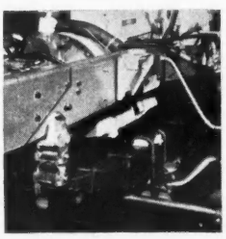

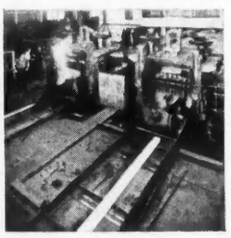

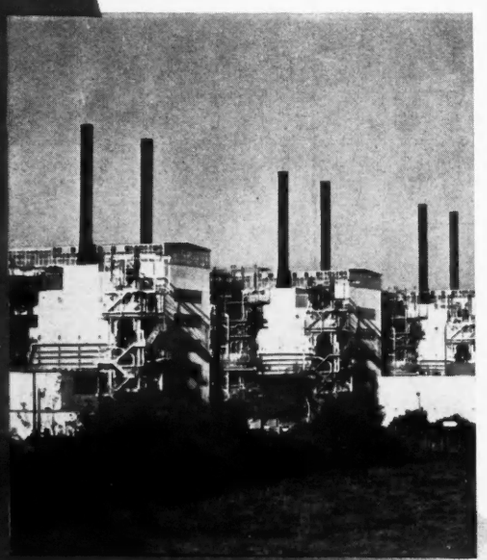

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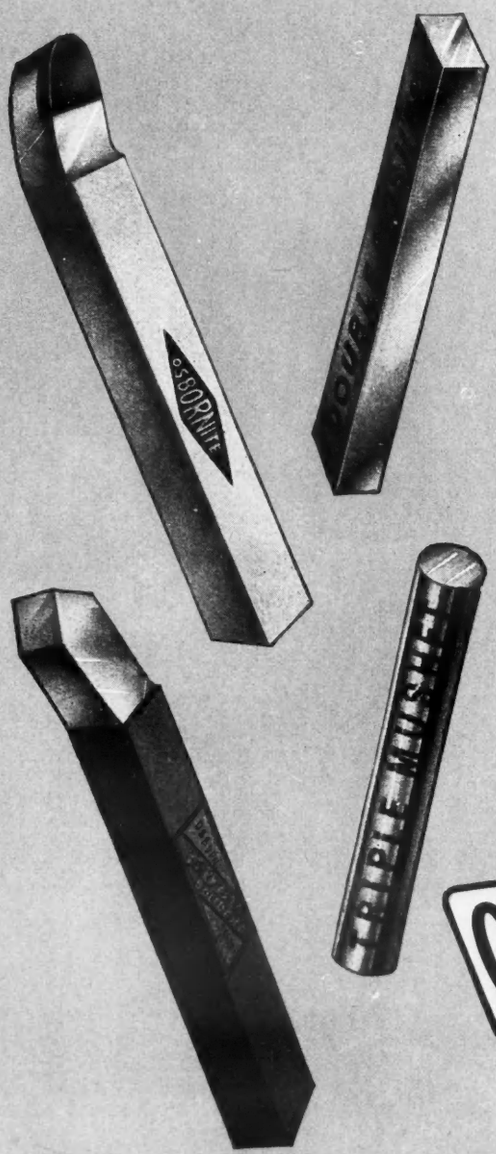

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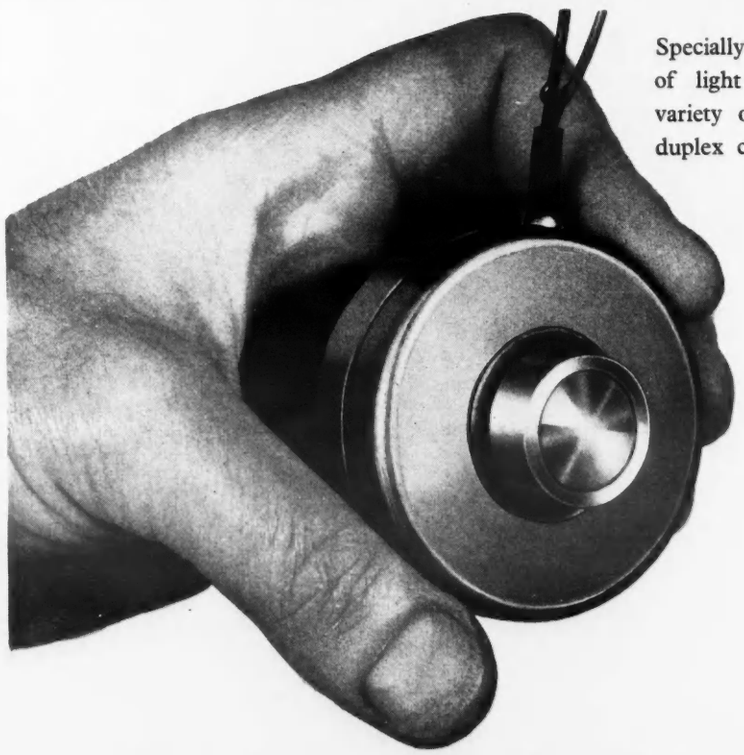

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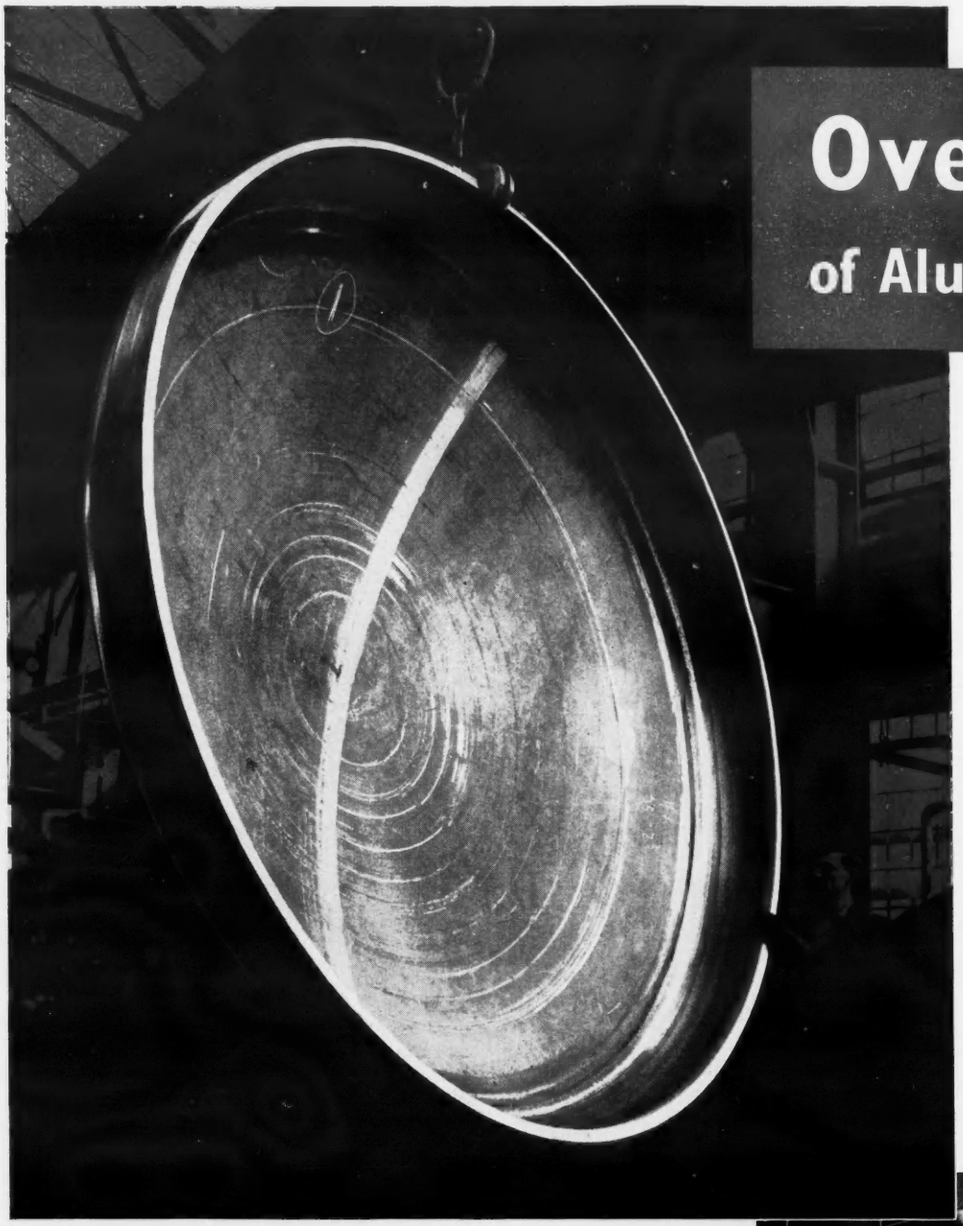

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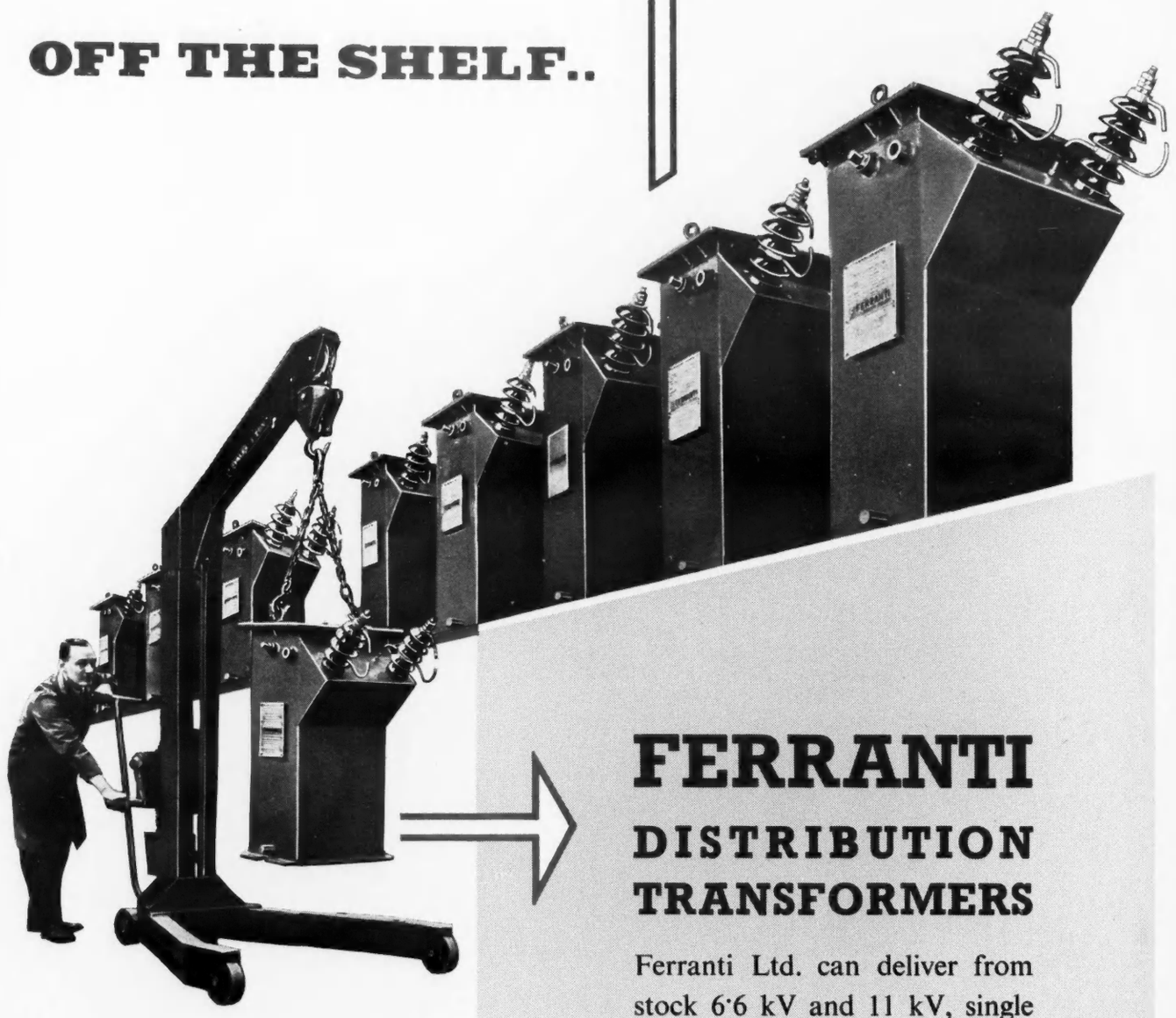

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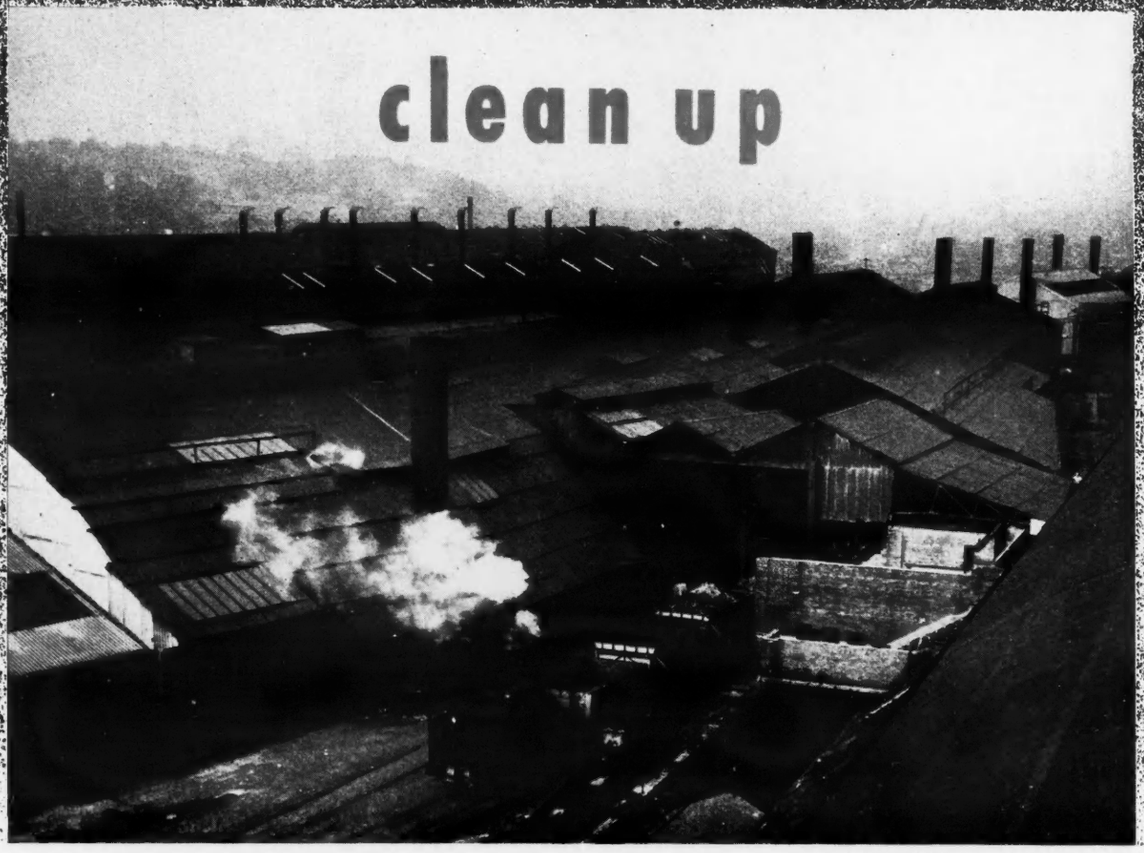

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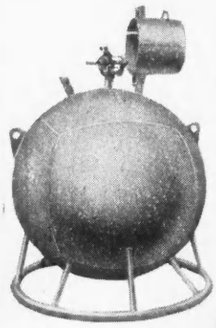

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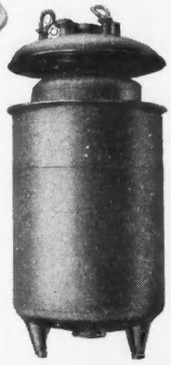

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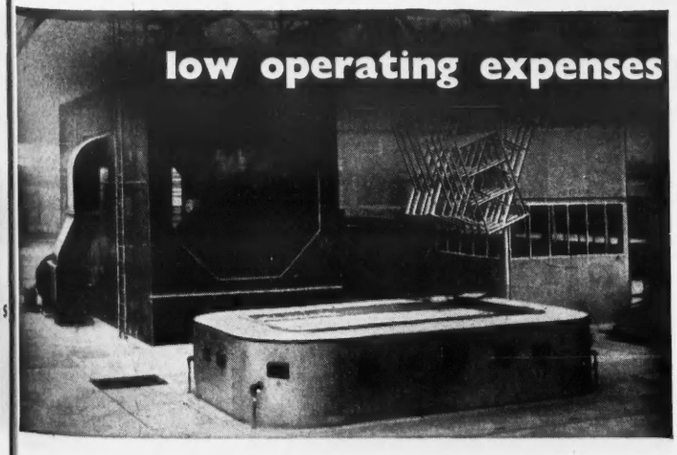

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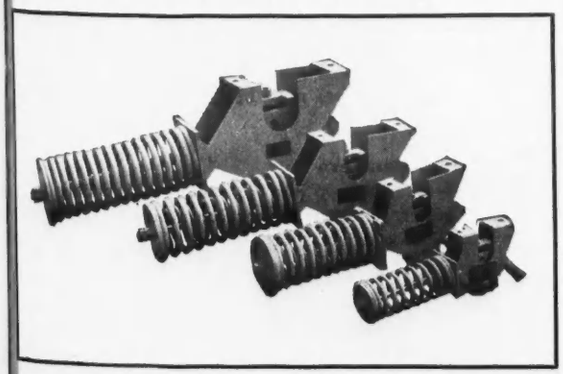

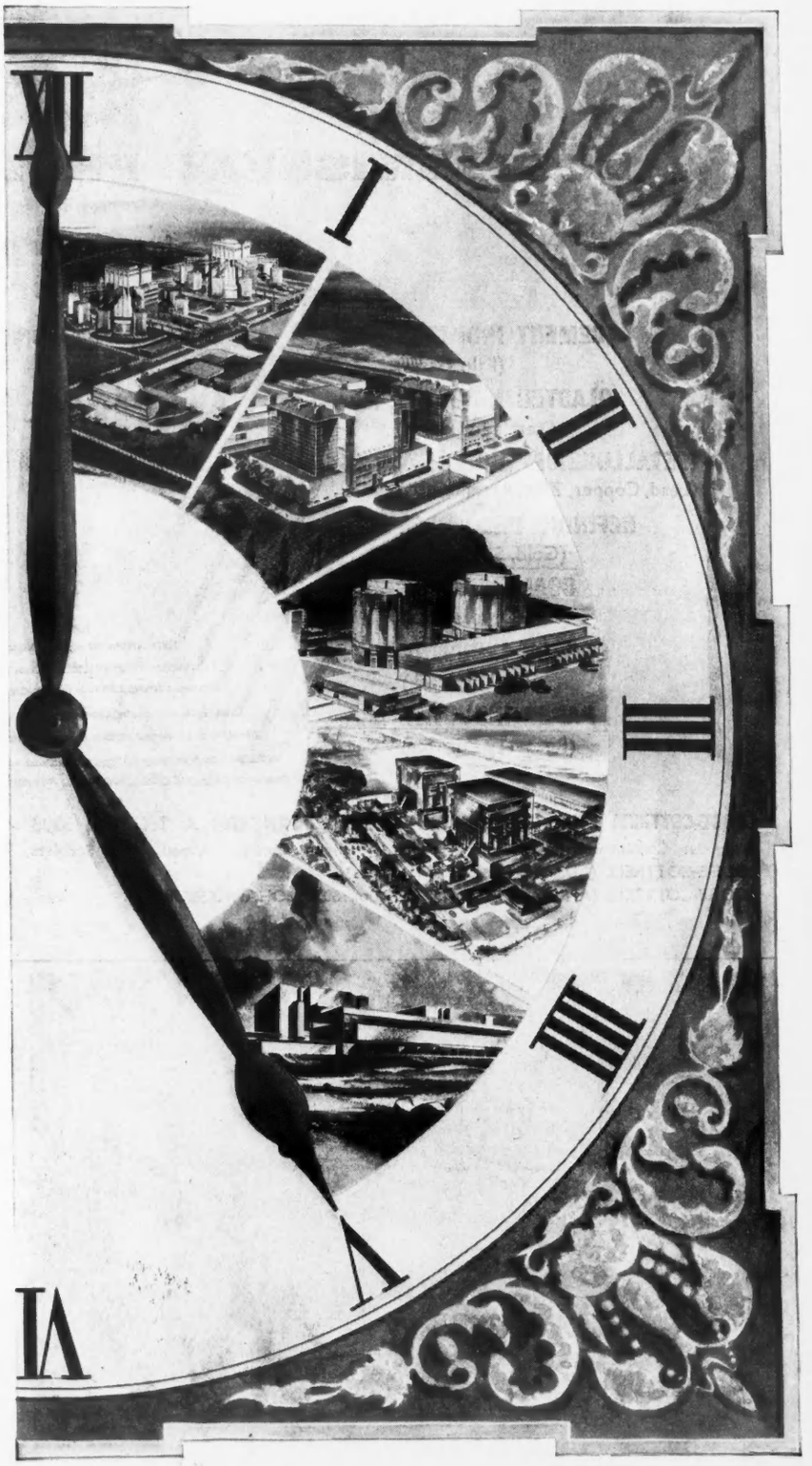

The illustrations above are artists' impressions of the Nuclear Power Stations at Berkeley (A.E.I.—John Thompson Nuclear Energy Co. Ltd.); Bradwell (The Nuclear Power Plant Company Ltd.); Hunterston (G.E.C.–Simon–Carves Group); Hinkley Point (English Electric, Babcock & Wilcox, Taylor Woodrow Atomic Power Group) and Trawsfynydd (Atomic Power Constructions Ltd.)

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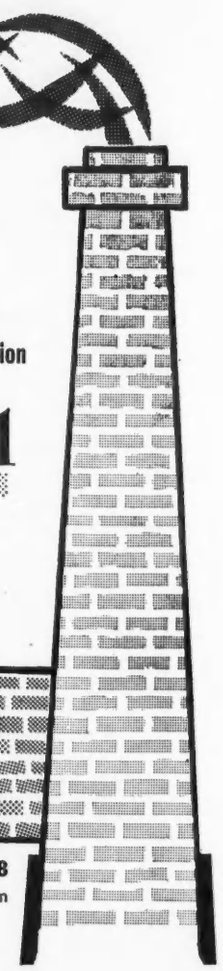

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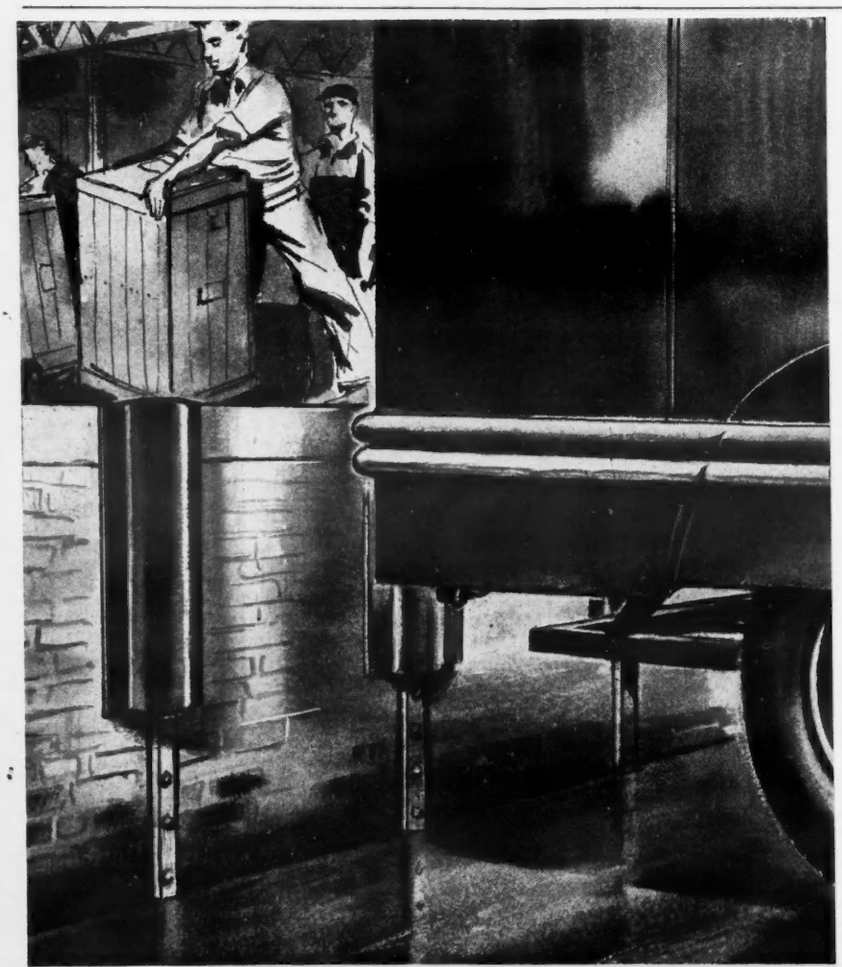

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THE ENGINEER

No. 5453 JULY 29, 1960 Vol. 210

EUROPE AT SIXES AND SEVENS

The debate in the House of Commons last Monday on European trade proved very enlightening and all who wish to appreciate better the various issues involved as a consequence of the creation of the European Economic Community of the "Six" and the European Free Trade Area of the "Seven" would profit by taking a look at the relevant number of *Hansard*. Despite difference of opinion on matters of detail the Members of the House showed themselves to be almost unanimous in rejecting any proposition that this country should accede to the Treaty of Rome (through the signing of which the EEC came into being); and also unanimous in pressing for negotiations which would improve the political and economic unity of Europe.

We confess that since the idea of a free trade area around the Common Market, which was widely supported in this country, was turned down by the Six, we have not been at all satisfied with our unhappy state of indecision revealed in our leading articles as to what we think the country should do next, especially as we have noted other journals coming out strongly for accession to the Common Market, now, on the best terms this country can get; or equally decisively against any such action. We have felt, however, that our state of indecision reflects fairly enough the true state of opinion upon the matter within the engineering industry. Politicians, it now appears, are equally unhappy about the situation and about equally indecisive about what to do next. Of course, the fear in this country, especially amongst industrialists, is that British products will be excluded by a tariff wall from a rapidly expanding market on the Continent, that in fact within a measurable number of years this country will have become an industrial backwater. As against that fear, however, there is the feeling that markets in the Commonwealth and in the world outside Europe must be retained since together they absorb some 75 per cent of our exports and provide some 75 per cent of our imports. Many people believe the fear to be exaggerated. One hankers, of course, after the original conception of a free trade area around the Common Market. But that idea seems to be now altogether dead. Where do we go from here?

For our part we suggest that at present there is very little hope of getting anywhere, anyhow, with the EEC; that this country is making too much of the possible economic damage that might be inflicted upon its trade by the EEC; and that it is making too little of the economic advantages to be derived from the existence of EFTA. We might, in fact, do better to cease pressing it upon the EEC that we are ready to negotiate some arrangement with it, and instead to concentrate upon the development of relations within EFTA and upon preaching to the world at large the high benefits to be expected within that association of states. For it is natural that those who have been concerned to bring the EEC into being are at present more interested in the internal development of that community than with negotiations to bring Britain or any other country into it; negotiations which must necessarily mean the recasting of the delicately balanced clauses of the Treaty of Rome. But if it can be shown that EFTA really works and is of high economic value to its seven participants readiness may well grow within the EEC to negotiate co-operation with it.

AUTOMATION ON THE ROAD

How many years will it be before a motorist, on approaching a main road, will be able to feed simple route instructions into some device in his car, and then leave the entire job of driving to automatic gadgets in the car and on the road? That may seem a far distant prophecy perhaps, but it does not seem so impractical, even if still a long way from practical attainment, after reading the abstracts on page 175 herewith from the lecture given last week by Mr. Flory of the Radio Corporation of America. Mr. Flory describes how automatic control is achieved under the simplified conditions of single-lane traffic, i.e., to keep the car "in lane" and to prevent it colliding with the car ahead. This is a first step in developing a comprehensive system of vehicle control which might be introduced in stages, each stage "compatible" with existing traffic and the whole system strictly following the "fail safe" concept.

To sum up the philosophy behind this work, which is a most fascinating and promising line of inquiry, we cannot do better than quote Mr. Flory's own words: "Aside from the personal safety aspects, the cost of accidents in property damage and loss of time is, in the United States, equal to the cost of fuel consumed. In addition, from a strictly engineering standpoint, any method of increasing the efficiency of movement of traffic resulting in better loading of the highways is just so much money in the budget. . . . Engineering improvements have practically eliminated mechanical failure as a factor in highway accidents. Throughway construction embodies all known safety considerations as far as physical construction is concerned. In the communication system between highway and car, or between car and car, the least reliable element is the human link which must receive the information, make a decision, and institute action, often within a fraction of a second."

This last factor is, therefore, being attacked with some success, as the lecture shows. What needs emphasising at this stage is that the results already obtained can be fruitfully applied immediately in certain special circumstances. For instance, at blind corners or where visibility is likely to be restricted, patterns of lights—a "flying tail" of lights Mr. Flory calls it—could be installed to give a driver indication of a vehicle ahead and its headway. Some such system could also be perfected to allow the mixing of moving streams of traffic. Mr. Flory pointed out that the Road Research Laboratory's new test track (which, incidentally, the technical press has not yet had a chance of describing in detail) offered good opportunities for testing such systems. Neglecting entirely the long-term possibilities of this research, it would seem that the

immediate results, though limited, are of such promise in a country afflicted as ours is with grossly inadequate roads, as to make energetic appraisal and application to the roads of these results a matter of importance and urgency.

MODELS FOR APPRENTICES

Not so very many years ago craft apprentices were taken on by engineering firms, were pushed straight into the production shops to work with and under a variety of skilled men, and were expected to pick up the necessary craft skill over a number of years. In certain trades other than engineering, and perhaps, still, in some engineering firms, that still remains the means whereby apprentices get trained. It was a method—if something without any apparent plan can be called a method—which must have been satisfactory enough in its day; for many living skilled men highly valued by the firms for which they work must have received just such training. But to-day matters are arranged differently. There has been growing an appreciation that a less haphazard method produces better results more quickly. At one time there was some tendency towards providing nearly the whole of the training in an apprentices' school separate from the production works, the apprentice entering the works proper only after spending two or more years in the school, by which time those in charge of his training could have ensured that he had attained a certain minimum standard of skill. But the modern trend seems, undoubtedly, to be to keep the time spent in the school down to one year, a period sufficiently long to give the apprentice the chance to show aptitude for a particular trade and to be given a good grounding in that trade so that he becomes immediately useful in the production shops and therefore becomes quickly at home in the new atmosphere.

But in such training schools the problem arises as to what the boys shall make. For it is very discouraging to all concerned if the bulk of the stuff made just goes for scrap. The point is discussed by James Wooding in a recent issue of the *Allen Engineering Review*, the house journal of W. H. Allen, Sons and Co., of Bedford. He points out that while standard exercises have a value, particularly in allowing careful and detailed measurement and assessment of results, they can lead not only to frustration amongst the boys but to " a particular kind of exhaustion in instructors " so that " personal deterioration inevitably occurs over a period of years ". There are two commonly used methods of avoiding this frustration of boys and trainers. One is to require of all the boys that they shall make certain tools for themselves, such as calipers, squares, scribing blocks, &c. Another is to import certain production jobs from the production shops. The former of those methods has everything to recommend it in that assessment of the results is relatively easy and because the articles once satisfactorily made are greatly valued by the boys. But there are pitfalls in the latter method. It is only too easy for the training centre to degenerate into a part of the production side by undertaking certain routine jobs not of special training value. However, subject to that proviso, taking real production work into the training centre is valuable; but works will differ in their ability, dependent upon what they produce, to provide jobs suitable for the training school. What Mr. Wooding points out—it is the prime object of his article—is that model-making can often provide an almost ideal solution to the problem. One advantage it has is that it brings trainee draughtsmen into the scheme of things because it falls to them to make the necessary modifications to the original drawings issued to the shops and to issue thereafter just as full a set of working drawings to the apprentices' school. Experience has shown that the arrival of the drawings in the school immediately arouses a great deal of interest, the more particularly as it is soon realised that all the boys at some time or other will have the opportunity to make some part of the model, or fit some part to it, or " test " it in operation. The resultant models, being true to scale and operable, are in demand for showing at exhibitions, &c. The building of them, of course, brings sharply home to boys the contribution each of their skills will make in the future to the building of similar full-scale machines. Though the firm to which Mr. Wooding belongs has long shown leadership in developing methods of training apprentices we are pretty sure that in this matter it is not the sole leader but only one amongst several. For we have noticed the same trend towards model-making in the training establishments of other firms. No doubt it is not a method which can be universally applied. But any firm having products of which working models could usefully be made would, we think, be well advised to give it a trial; and to any firm accustomed to producing " one off " designs the making of a model, especially if it can be completed before the full scale article, may have the very real value of revealing any deficiencies in general appearance or layout or possibly graver faults in the plant overlooked by the design and draughting staff. How cock-a-hoop all concerned in a training centre would feel if the design staff, having examined a model made in the school, were to decide upon modifications of the full-scale article!

The Engineer—100 Years Ago (JULY 27, 1860)

" REPULSION "

" M. Faye has just communicated to the Academy of Sciences another series of experiments made with Ruhmkorff's inductive apparatus, in order to verify the repulsive force of incandescent surfaces. We stated, a short time ago, in describing the first experiments, that a platinum plate, rendered red-hot *in vacuo*, would repel the rose-coloured flame which is produced in the receiver by an electrical current ; but that the blue flame which is accumulated at the negative pole showed it was but slightly influenced by the heat of the same lamina. At M. Faye's suggestion, M. Ruhmkorff has this time constructed a new apparatus, consisting of a large glass balloon pierced with four holes armed with brass sockets. The electrodes of Ruhmkorff's machine pass through the two holes situated in a vertical line ; two copper wires acting as horizontal conductors pass through the two which lie in a horizontal line, supporting a thin lamina of platinum, at equal distances from the knobs of the electrodes inside the balloon. The lamina is raised to a white heat by the voltaic current of four of Bunsen's elements. The balloon being previously exhausted, and one of the electrodes brought into communication with the positive pole of Ruhmkorff's machine, the horizontal conduction communicating with the negative one, the blue flame at once begins to skim the surface of the lamina. Now if the current of Bunsen's elements be made to pass through the same horizontal conduction, and consequently through the lamina, so as to raise its temperature to a white heat, the strata of blue flame which were previously in contact with the lamina will rapidly recede from it. The distance will increase or diminish in proportion to the heat, and will be entirely obliterated when the lamina returns to its ordinary temperature. Thus the repulsive effect of incandescent surfaces appears to be placed beyond a doubt. M. Becquerel having allowed a small quantity of air to penetrate into the balloon, the distance of the blue flame from the lamina diminished, but not very much—a larger quantity of air reduced it to nought. These experiments are to be continued."

Nuclear Power Progress in Britain

U.K. ATOMIC ENERGY AUTHORITY'S REPORT, 1959-1960

No. II—(*Concluded from page* 147, *July* 22)

The sixth annual report of the United Kingdom Atomic Energy Authority, published on July 13,* *covers the year ended March* 31, 1960. *The following extracts taken from the report deal with fuel element production and the Authority's general programme of research and development, including work on radioactive isotopes and controlled thermonuclear reactions.*

COMMISSIONING of most of the Springfields uranium production plant was completed in the year under review. In particular the new uranium concentrate purification plant utilising an improved solvent has been successfully brought into operation.

In the original concept of the new plant it had been decided to use a new method, involving fluidisation techniques, for converting uranium nitrate into tetrafluoride, an essential step in the manufacture of the metal. It was intended that this process should be continuous and the product cheaper. It was appreciated that considerable teething troubles would be encountered and a full-scale prototype unit was therefore built. Initial operation of the prototype unit revealed problems of stability, of corrosion and of the efficient recovery of some of the reagents, in particular the hydrofluoric acid. The majority of these problems have been overcome and the prototype plant is now operating as a production unit yielding uranium tetrafluoride of good quality at the design throughput.

Fuel Element Production

The new fuel element production lines have been designed to meet the requirements of the nuclear power programme and of the Authority's reactors and will, when running at full capacity, be capable of an output of more than 300,000 uranium metal fuel elements per annum. The manufacture of the first fuel charges for the civil power stations at Bradwell and Berkeley was about to start at the end of the year. Reactor proving trials had indicated the need for changes in the detailed design of some components which, at this late stage, had caused some difficulties, but these were being overcome as rapidly as possible.

Because even a very small number of failures is important, the proving trials must be carried out on a considerable scale to demonstrate the required degree of integrity : thus in the case of Calder and Chapelcross reactors the maximum percentage of failures that could, to date, be attributed to defective welds is of the order of 0·005 per cent. Consequently a new weld arrangement or manufacturing technique would need to demonstrate a comparable or better performance in proving trials. Proving trials on the final design of the fuel elements for Bradwell, Berkeley, Hinkley Point and Hunterston during the past year have involved the manufacture of large numbers of prototype fuel elements during the commissioning period in the new factory.

To meet demands for fuel elements for new research reactors or for experimental purposes, a new general purpose metallurgical shop has been built ; production of uranium oxide fuel elements for the A.G.R. prototype at Windscale was begun.

*H.M. Stationery Office. Price 5s.

Research and Development

A new accelerating machine came into operation at Harwell in November, 1959, when the Neutron Project Laboratory started work.† The machine will provide intense bursts of neutrons which can be used, in the time-of-flight method, to make precise measurements of the neutron cross sections for various nuclei over a wide range of energies. The machine incorporates a linear accelerator capable of accelerating electrons to 30MeV ; the energetic electrons strike a target of mercury and release gamma rays which in turn release neutrons from a uranium target. The intensity of the neutron pulse is increased some tenfold by using in this target a sub-critical assembly of enriched uranium, in which neutron multiplication takes place, though without reaching the critical condition for a self-sustaining reaction

This powerful pulsed neutron source with its sub-critical neutron-multiplying assembly also makes possible studies of certain aspects of the fission process, and of other neutron interactions, which were previously impracticable. Its primary use, however, will be for the measurement of all the cross-sections, for fissile and fertile and for structural material, needed for the thermal reactors of the power programme, work which will occupy a large team of scientists for several years.

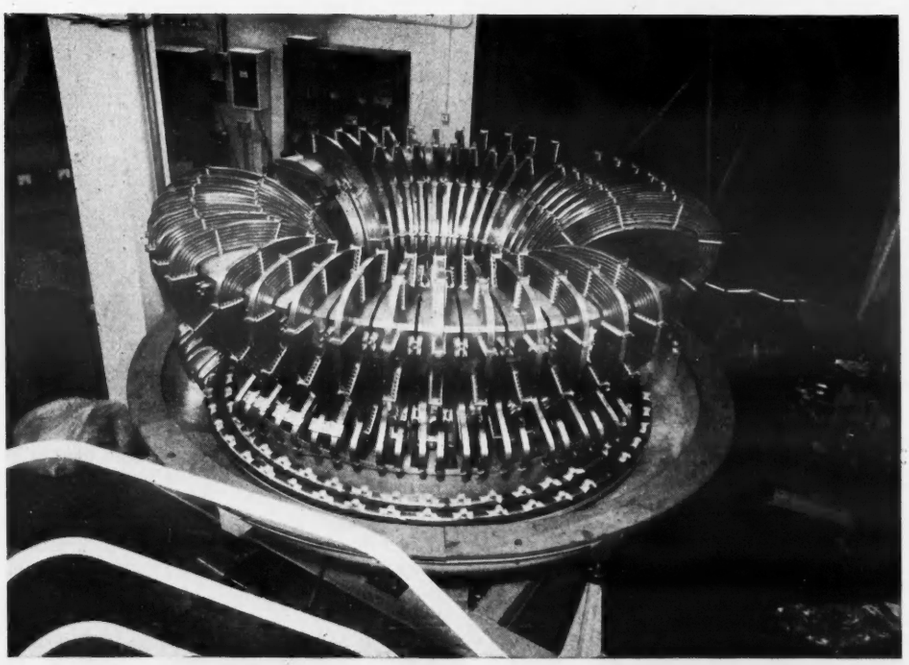
†THE ENGINEER, Nov. 20, 1959, page 633

An understanding of the physics of fast reactors requires detailed knowledge of the interactions of neutrons over a wide range of energies with both fissile and structural materials and with likely coolants such as sodium metal. The aim of experimental work at Aldermaston, which at present is carried out with the 6MV and 3MV electrostatic generators, is to contribute to measurements of fast neutron scattering and of capture cross sections of neutrons emitted in the fission of uranium and plutonium isotopes and other similar data, all of which can be used to predict the critical size, breeding ratio and other properties of a fast reactor.

A large heavily shielded liquid scintillation counter has been developed for the study of neutron emission in fission. Accurate data are now available for 14MeV neutrons and the measurements are being extended to cover a wide range of neutron energies. The apparatus can also be used to study neutron capture reactions and neutron emission in (n, 2n) and (n, 3n) reactions. Selection of incident neutron energy is achieved by moving the assembly around a suitable target which is bombarded by protons or deuterons from the electrostatic generator.

An important innovation in the technique of studying the elastic and inelastic scattering of neutrons was the introduction of a detector which provides complete discrimination against gamma rays. With incident neutrons of about 4MeV, it has been found that the background in the detector can be reduced by an order of magnitude by a combination of better shielding and gamma ray suppression.

The tandem electrostatic generator at Aldermaston has operated very satisfactorily during the past year. Beams of protons and deuterons with energies up to 12·5 MeV have been used in inelastic scattering and reaction studies, and most recently energetic oxygen ions have been used to investigate the Coulomb excitation process. In Coulomb excitation, the bombarding ion does not enter the nucleus but transfers energy to it through the relatively long-range electric and magnetic fields. An accurate theory of



Magnetic circuit (under construction) of a large spectrograph used, in conjunction with the tandem Van der Graaff generator at the A.W.R.E., Aldermaston, for the accurate analysis of charged particles from nuclear reactions

Coulomb excitation exists, and the process is particularly valuable for investigating those states of nuclei which arise from the *collective* motions of the nucleons. Heavy ions, such as those of oxygen, are particularly suitable for Coulomb excitation studies, and are readily accelerated in the tandem to energies of about 35MeV. The Coulomb excitation process itself is being studied in detail, and low lying energy levels of both light and heavy nuclei have been investigated.

The accompanying illustration shows, under construction, the magnetic circuit of a large spectrograph used for precision analysis of charged particles from nuclear reactions. The instrument is used with the tandem Van der Graaff generator at Aldermaston and it contains twenty-four gaps, each of which is used to analyse reaction products, so that simultaneous measurements of angular distributions and energies are obtained.

Solid State Physics. — A fundamental experiment has been carried out in the realm of solid state physics using lithium isotopes. An important discrepancy has existed between observed thermal conductivities of dielectric crystals at low temperatures and the theoretical predictions for perfect crystals. It has been suggested that the discrepancy is due to the presence of isotopes which disrupt the periodicity of the crystal lattice and increase the thermal resistance, and two theories for this effect have been published. Measurements have been made at Capenhurst, in conjunction with university scientists, of the thermal conductivity of single crystals of lithium fluoride containing various relative concentrations of the isotopes lithium-6 and lithium-7 in the temperature range 10 deg. to 90 deg. K. A change in thermal resistance with isotopic concentrations is observed but the results fit neither of the theories previously advanced. A new theoretical treatment is in good agreement with the experiments on lithium fluoride and also with published observations on a wide range of crystals containing known concentrations of point imperfections.

Radiation Chemistry and Nuclear Technology.—There is a growing demand for a more detailed knowledge of the behaviour of the system carbon-dioxide/carbon-monoxide/graphite under irradiation. These studies are aimed at determining the basic parameters that affect the rates of the reactions. In the first experiments, gas was circulated over graphite in an apparatus in " Bepo." These demonstrated that the temperature has no appreciable effect on the rate at which carbon monoxide is produced from carbon dioxide and graphite over a temperature range from 100 deg. to 600 deg. Cent. Above the latter temperature there is a marked increase in the rate, caused presumably by a purely thermal reaction. When the experiment is carried out in a sealed apparatus, a steady-state concentration of carbon monoxide is attained as a result of competing forward and back reactions. Similar experiments in " Dido " at 400 deg. to 500 deg. Cent. have demonstrated that the amount of surface oxide present (i.e. oxygen chemi-sorbed on active sites on the graphite surface) has a marked effect on the rate of the radiation-induced carbon monoxide formation. The relationship between carbon weight loss and carbon monoxide production has been obscured by weight changes caused by thermal and radiation-induced degassing during the experiments and by changes in the condition of the surface oxide.

In another group of experiments, the behaviour of carbon-14 incorporated in samples of graphite, during irradiation in sealed tubes containing various mixtures of carbon monoxide and carbon dioxide, is being studied at 80 deg. Cent. Transport of carbon to the gas phase takes place in all mixtures, even in pure carbon monoxide. The rate of transfer is affected by gas composition and by pretreatment of the graphite.

The reactions between pile graphite and other gases such as hydrogen and nitrogen in the presence of radiation have also been studied. There is a slow production of methane in the case of hydrogen whereas there is no measurable reaction with nitrogen below 650 deg. Cent.

A rather different subject of study has been the radiation chemistry of the liquids proposed as moderator and coolant in the organic-liquid-moderated reactor mentioned above. The liquids are commercial mixtures of organic compounds known as polyphenyls. The reactor system was first tried in the United States and the radiation chemistry has been studied both in American laboratories and at Harwell.

The polyphenyls have quite high boiling points. It has been shown by American workers that their stability to radiation is high and that the main products of such decomposition as does take place are hydrogen gas and higher polyphenyls which are themselves soluble in the original liquid. The result is that the viscosity of the liquid does not rise quickly to unacceptable levels and no solid material is deposited.

The radiolysis has been studied with the electron beam from a 2MV Van de Graaff machine, with high intensity gamma rays, and with neutrons from the " Bepo " reactor. It has been shown that the radiation yields for the breakdown of the lower polyphenyls at high temperatures in " Bepo " are markedly higher than those obtained using electron and gamma radiation. All this evidence suggests that the linear rate of energy transfer in the tracks of the ionising particles is an important factor in determining the decomposition of these unsubstituted aromatic hydrocarbons.

Prolonged irradiations of Santowax-R, a commercial mixture of isomeric terphenyls, at 350 deg. Cent. in the reactor have shown that the rate of breakdown decreases continuously with increased polymer content—to half the initial rate at 30 per cent polymer and to approximately one-quarter at 50 per cent polymer. This decrease is smaller than was expected from previous work at lower doses.

The viscosity of the irradiated material increases rapidly beyond a polymer content of 50 per cent to an extent dependent on the temperature. The increase in density is less pronounced.

The rate of breakdown of Santowax-R in a pile increases very rapidly in the temperature range 400 deg. to 420 deg. Cent. When some provision is made for possible temperature excursions, it seems unlikely that a terphenyl coolant could be used at a bulk temperature higher than 370 deg. to 380 deg. Cent.

A number of other materials has been examined but so far nothing has been found which is superior to the polyphenyls and current design studies of organic liquid moderated reactors are based on their use.

Criticality Calculations.—In the design of production plants, careful attention has to be given to the possibilities of criticality. Considerable technical work has been undertaken to back particular design studies, and in addition a more generalised study has been undertaken. A unified theory has been checked against American experimental results and very good agreement has been obtained, the theory erring a little on the side of safety. Fundamental studies have been carried out on criticality calculations for water-moderated uranium lattices of low enrichment and this work gives close agreement with published experimental results. Calculations have also been made of the criticality of lattices of irradiated uranium bars. A combination of theoretical and empirical methods has been used to predict criticality data for homogeneous systems moderated by water and having as fissile material 93 per cent uranium-235, plutonium, and less than 5 per cent uranium-235 respectively. Where experimental checks are available, they give good agreement.

Research on the Applications of Radioisotopes.—Work has continued in the Wantage Research Laboratory on the application of radioisotopes, especially in industry. Thus the method of fluorescence spectroscopy, using radioactive sources, has been applied to measuring very thin surface coatings. Instruments based on this and a related technique have been used industrially to measure metal coatings about a ten-thousandth of a centimetre thick, and also the thickness of ink on paper.

Radioactive tracers continue to be applied in new ways. In the electro-plating industry, the modes of action of some additives commonly used to brighten and level the plated deposit have been elucidated for the first time with the help of tracers. The tracers were detected by micro-autoradiography in which the active material is made to take a photograph of itself.

In the development of fuel element cans for power reactors, tracers have been used to identify and locate constituents of the metal such as might lead to failure in operation. A method has also been devised for testing fuel element cans for incipient leaks, using krypton-85 gas as a tracer. By similar methods, leaks at a rate less than one ten-thousandth of a cubic centimetre in a year can be detected in small components such as transistors.

By tracer methods, the rate of flow of liquid in closed channels can now be measured with an error of less than one part in two hundred ; this is an improvement in both accuracy and convenience over established methods. Measurements of this kind are important in commissioning hydro-electric generators. Similar techniques have been adapted as a means for detecting leaks in the effluent pipeline at the Atomic Energy Establishment, Winfrith.

A pilot scale plant for irradiating packages of materials with gamma rays has been built at Wantage to use, at first, 120,000 curies of cobalt-60. Eighty per cent of the capacity of this plant is reserved for sterilisation by manufacturers of medical equipment, for clinical trials and for packaging and storage tests before full-scale production. The remainder of the capacity is taken up in the research and development programme of the Technological Irradiation Group. The first industrial gamma-ray sterilisation unit in the world has been completed in Australia and 150,000 curies of cobalt-60, supplied by the Authority, have been installed. Further cobalt sources of up to 500,000 curies have been ordered for extensions to the plant.

Mass Spectrometry. — A mass spectrometer has been developed at Capenhurst for the analysis of the active species present in gas/solid chemical reactions. The particular problem which was in mind when the work was commenced was the elucidation of the carbon-dioxide/graphite reaction under irradiation, but the instrument finally developed

will be of general application. The instrument has been designed to study reactions at gas pressures up to 2 atmospheres and in favourable conditions to detect active species down to a level of one part per million or better. The mass spectrometer is a standard sector type machine incorporating two new techniques for the analysis of trace components in gases. A molecular beam inlet system is used to allow short-lived species direct passage to the mass spectrometer ion source ; a chopping technique has been devised which enables wanted a.c. signals from the inlet system to be separated from unwanted d.c. signals arising from the background ions in the instrument.

Gas Bearings.—Current development in gas-cooled reactor technology has called for mechanisms to operate either unlubricated or lubricated solely with the gas that is being circulated.

Basic studies have been made of the friction and wear behaviour of materials in reactor coolant environments at high temperatures. It has been found that in carbon dioxide and helium both wear rates and friction coefficients can vary greatly with temperature. Low-chromium alloys show the greatest variation, whilst high-chromium alloys give little change between ambient temperature and 400 deg. Cent. It is known that surface oxide films can have a marked influence on friction and surface damage. Least wear rates were, in fact, obtained with low-chromium alloys under conditions where visible surface oxidation occurred. Ordinary rolling contact bearings running unlubricated have also been studied under similar conditions. Experimental life-load curves for the bearings have been determined and the bearing wear has been measured and analysed. This work has built up a considerable background of knowledge of what can be achieved with such ordinary bearings under reactor conditions.

The alternative solution of using the gas which is being circulated as a lubricant has led to a study of the possibilities and applications of gas bearings. Thus, detailed investigations into the load-carrying capacity and vibration characteristics of self-acting and externally pressurised journal bearings and thrust plates have been instigated.

As a result of this gas bearing work, a peripheral gas-bearing compressor has been developed for the circulation of gases in reactor loops and other closed systems. At a relatively high pressure ratio where low mass flow is generally required, the peripheral type compressor best meets these requirements. The machine developed consists of a motor unit, the rotor being mounted on a pair of gas bearings, and an impeller unit, also mounted on a pair of gas bearings, the two units being connected by a quill shaft. The whole machine is totally enclosed and built to a very tight vacuum specification. It will handle all gases that do not react with the motor winding. Various sizes of units have been built covering the range 7 h.p. to 60 h.p.

Flash-Radiography.—Considerable progress has been achieved at Aldermaston in the provision of short duration radiographs of systems opaque to ordinary light and moving at high speed. To this end special low inductance Marx generators have been constructed giving a single voltage pulse of 1MV or 2MV with a duration of order 0·2 microsecond. These generators are believed to have appreciably better performance than any comparable generator for which published information is available.

To work with these generators special X-ray tubes have also been developed, with both hot and cold cathodes. In order to get good resolution and high dose the design of the tube has been concentrated on getting an X-ray source the size of which is of the order of 2mm in diameter.

A 30 MeV linear accelerator has been installed to provide a source of pulsed gamma rays of even greater penetrating power. This accelerator is an early experimental model built at Harwell, which has been modified and adapted in various ways to provide an intense burst of gamma rays lasting for a time of the order of 0·2 microsecond.

Very-High-Speed Cameras.—Very-high-speed cameras were originally developed at Aldermaston to record the growth of an atomic explosion during the first few millionths of a second. To-day much improved designs are making important contributions to our knowledge of pinched discharges in controlled thermonuclear reaction work, and A.W.R.E. cameras are used in this connection both at Harwell and at Aldermaston.

Two types of mechanical very-high-speed cameras are manufactured at Aldermaston. One, the streak camera, records along a length of film the size of a light source which is varying with time ; the other, the framing camera, produces individual pictures at intervals on a strip of film.

The light entering either type of camera, through a suitable lens, is directed on to the surface of a rapidly rotating steel mirror, from which it is reflected on to a stationary strip of photographic film. Thus the light streaks across the film and is recorded as such in the streak camera. From examination of the film after development it is possible to measure the size of the light source at any specific time over a total period of 12 or 25 millionths of a second, depending on the mirror speed.

By focusing the entering light on the mirror surface and placing a number of lenses in an arc between mirror and film it is possible to obtain a series of individual pictures. With the mirror rotating at 300,000 r.p.m. and with ninety lenses in such a camera, the time between each picture is one seven millionth of a second. Each picture is exposed for one ten millionth of a second. In such a camera the mirror has a long life. Mirror speeds as high as 400,000 r.p.m. are also available, but then bearing wear limits the number of runs. These very high speeds are obtained by means of a compressed air turbine drive. The mirror itself spins in a vacuum.

A third type of very-high-speed camera is made which takes a single picture with an exposure time of one ten millionth of a second, using a Kerr cell shutter. This cell contains a special liquid through which the light will pass only as long as a suitable voltage is applied to it. Thus the timing here is electronic.

Controlled Thermonuclear Reactions

"Zeta" and "Sceptre."—"Zeta" (at Harwell) is a ring-shaped apparatus in which deuterium gas is heated to high temperatures by passing through it a large pulse of current (up to 200,000A) ; the result is a "pinched" discharge, since the electromagnetic forces associated with the current cause the gas to be compressed inwards and so to move away from the walls of the containing tube.

Initial experiments on "Zeta" showed that, although the passage of gas currents of up to about 200,000A caused the bulk of the gas to be compressed away from the torus walls, there was an excessive loss of energy from the gas during the current pulse. The rate of loss of energy from "Zeta" was such that the whole of the energy stored in the gas at any one time was being lost in one ten thousandth of a second (this time is known as the energy containment time). Because this time is small compared with the period of the current pulse, the temperature of the gas rose rapidly during the early part of the current pulse, but then failed to rise further.

During the past year the stored energy supply and the stabilising magnetic field supply of "Zeta" were both increased by about six times. As a result, gas currents of up to 800,000A were obtained. This made it possible to operate at considerably higher gas pressure. However, the increase in current has not led either to a substantial increase in the gas temperatures achieved or in the energy containment time. The exact mechanism by which the energy is lost depends on the discharge conditions (current, pressure, axial magnetic field) but the primary cause of the energy loss is likely to be that the configuration of plasma and associated magnetic fields is hydromagnetically unstable, as is confirmed by recent theoretical work.

"Sceptre IV" was brought into operation in November, 1959, at Aldermaston Court (Associated Electrical Industries, Ltd.). It is similar to "Sceptre III," but has a perfect toroidal shape and a more uniform axial magnetic field, and has been operated at currents up to 480,000A. It has not resulted in ion or electron temperatures higher than those in "Sceptre III."

Theoretical studies have suggested that a necessary, though perhaps not a sufficient, condition for stability is that the current can be made to flow in a thin skin on the surface of the ionised gas. It is known that such a surface current is produced if the current is made to increase sufficiently rapidly at the beginning of the current pulse, but for technical reasons a sufficiently rapid rate of rise of current cannot be obtained with either "Zeta" or "Sceptre." An experiment known as I.C.S.E. (Intermediate Current Stability Experiment) is therefore being designed, in which the current will rise fast enough to produce a skin effect. Furthermore, theory suggests that hydromagnetic stability can be achieved if an additional stabilising magnetic field is applied outside the plasma ; and this requirement is also incorporated into I.C.S.E.

The object of the experiment is to investigate the stability of this improved "pinch" configuration, and to check the main predictions of present stability theory. Thus although the apparatus is aimed at producing certain definite conditions, I.C.S.E. is being designed so that many of the parameters affecting stability can be varied over a wide range. The achievement of hydromagnetic stability may not be sufficient since other sources of instability in plasmas are known to be possible. I.C.S.E. will essentially be a large-scale experiment in plasma physics.

The design of this experiment is now well advanced, and orders have been placed for some of the main components. The apparatus will be erected at the Culham Laboratory.

Other Plasma Physics Experiments.—During the past year work continued on a number of other plasma physics experiments at Harwell. Three examples of such work are given below.

Theoretical considerations made by Alfven in 1942 predicted that hydromagnetic waves could be propagated in the joint presence of a magnetic field and a plasma. Because of

the importance of these Alfven waves, an experiment was undertaken to demonstrate their existence. The velocity of propagation of the disturbance was found to agree closely with the theoretical value for the velocity of Alfven waves. A similar experiment was performed almost simultaneously at the University of California.

In order to investigate some of the theoretical predictions about the stability of a pinched discharge, experiments were continued with cylindrical systems. All the results obtained so far can be explained qualitatively in terms of hydromagnetic stabilities.

Experiments were made on " Zeta," by members of the National Bureau of Standards, Boulder, Colorado, U.S.A., which demonstrated, for the first time in a laboratory, the propagation of electromagnetic waves in the so-called " whistler " mode. These waves have been known for many years as a form of radio atmospheric, due to lightning flashes. It is thought that the low frequency part of the lightning signal is propagated along the lines of the earth's magnetic field through the plasma formed in the extreme upper regions of the atmosphere. This medium is highly dispersive so that when the signal is received at the other end of the line of force, the original signal becomes a whistle of steadily decreasing pitch. The experiments reproduced this phenomenon by propagation of 10cm waves (the appropriately scaled wavelength for the apparatus) through the magnetised plasma in " Zeta."

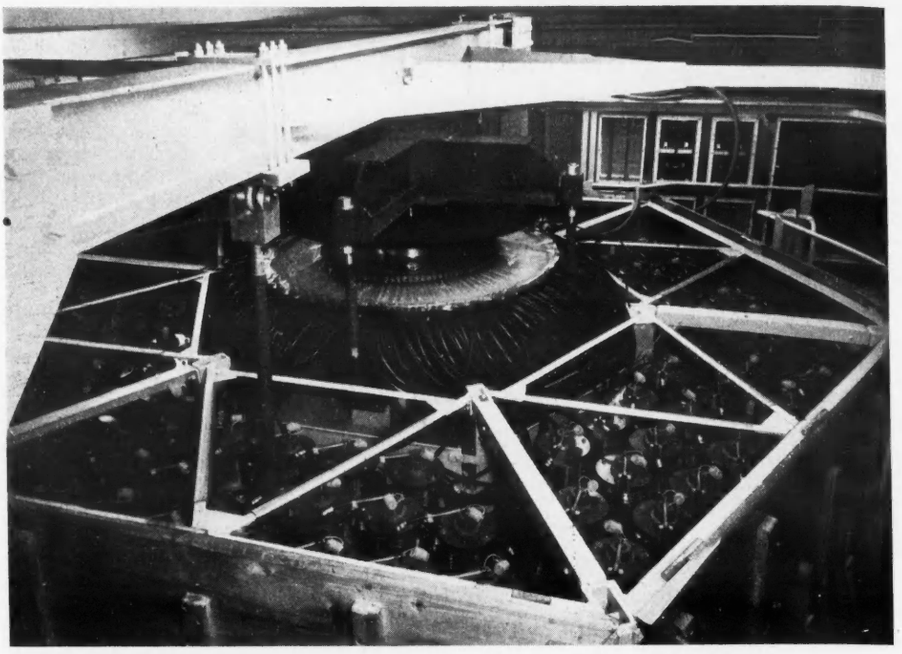
In addition to the intrinsic interest of the laboratory experiment, it is hoped that this phenomenon, which has already been used for experiments in the outer atmosphere, can be used to determine many of the plasma conditions inside devices such as " Zeta."

Considerable progress was made, in collaboration with industrial firms, in solving the formidable technological problems associated with the production and control of currents in the 1,000,000A range, and in the development of methods of torus construction to withstand the severe conditions expected in experiments such as I.C.S.E.

Work at the Atomic Weapons Research Establishment.—Research continued on various types of pinched discharge in hydrogen and deuterium gas at low pressure. Very low inductance condenser banks were used with stored energies up to a maximum of about 50 kilojoules. Part of the " Oswald III " fast condenser bank is illustrated here.

A detailed study was made of a fast pinching discharge in a straight tube between metal electrodes. It was found that large currents always build up outside the central plasma column near the walls when the total current in the tube rises very rapidly. As a result, heating and containment of the central plasma are limited, and the energy input to the gas never exceeds that at the first pinch (maximum temperature achieved 3,000,000 deg. K.). Attempts to increase the temperature by increasing the voltage across the tube only resulted in earlier appearance of wall effects with no appreciable gain in heating. Up to the time of the first contraction, a significantly greater amount of energy goes into the gas than into the magnetic field when the current rises very rapidly ; for slowly rising currents, more energy always goes into the magnetic field than into the gas, which is a less desirable state of affairs.

Many new and interesting results were obtained in the study of θ mode discharges in which the current flows in a circular path around the axis of the discharge tube. A magnetic field appears inside the tube as soon as the current begins to flow in the surrounding primary single turn coil and some of this field may be trapped by the annular current sheath formed inside the discharge tube. The trapped magnetic field may persist for a time greater than a half cycle of the current, so that a configuration may arise in which the field within the plasma sheath has a direction opposite to that outside the plasma. This trapped reversed magnetic field has a very important influence on many properties of θ mode discharges, and much effort has gone into its study. Ultimately, however, it is hoped to minimise and if possible eliminate the trapped field by careful control and preionisation of the gas before the main compression field is applied.



" Oswald III " fast condenser bank at the A.W.R.E., Aldermaston, showing the trigger pulse unit in the centre and the spark gaps surrounding it

High-speed photography of the discharge looking along the axis revealed a well defined plasma sheath which implodes rapidly towards the tube axis and then oscillates or " bounces " between the trapped magnetic field and the field outside. The frequency of the sheath oscillations can be obtained either from analysis of photographs or from the response of a very small magnetic probe placed on the tube axis. Since the plasma does not reach the probe until the late stages of the discharge, its indications are quite reliable and reproducible. They confirm and extend the information obtained from photographs, and clearly demonstrate the existence of reversed fields in certain circumstances. Observations and measurement of the frequency of the sheath oscillations are valuable as it is then possible to deduce directly the mass of ionised gas in the sheath.

In the fifth annual report reference was made to the fact that a small group at A.W.R.E. was considering methods of building up a plasma by injection and trapping of hot ions in a suitable magnetic field configuration. This line of research is being pursued actively elsewhere. The experiments planned at A.W.R.E. are on a small scale, and involve the injection of a beam of neutral atoms, equivalent energy 30 keV, into an arc running along the axis of coils which provide a magnetic mirror field. Some of the neutral atoms will be ionised in their passage through the arc and will therefore be trapped within the magnetic field region.

In order to assess the feasibility of various injection schemes for building up a plasma from high energy particles, it is necessary to have accurate quantitative information about the various interactions that occur between beams of fast particles and the common gases. Particularly important is the interaction between fast molecular and atomic hydrogen ions and hydrogen gas, and it was apparent at the 1958 United Nations Geneva Conference on the Peaceful Uses of Atomic Energy that there existed considerable discrepancies between the results of Russian and American work in this field. An extended series of experiments by a new method based on the detection of individual particles, and therefore not subject to the uncertainties associated with the detection of neutral beams, has been completed at Aldermaston. The new results, as well as providing the more accurate quantitative data required for the C.T.R. programme, provide new insight into the mechanism of collision processes between fast ions and atoms.

Culham Laboratories.—During the year the Authority reconsidered their previous decision to move controlled thermonuclear research from the Atomic Energy Research Establishment, Harwell, to the Atomic Energy Establishment, Winfrith, and concluded that, because the project will, for some years, be concerned with basic studies, they should seek a site near to the A.E.R.E. and the National Institute for Research in Nuclear Science (both at Harwell) and to Oxford University. A site of 175 acres on the former Royal Naval Air Station at Culham was chosen as the best site of adequate size and with good communications to meet this requirement, and the Authority accordingly sought planning permission to develop this site as a thermonuclear and plasma physics research centre.

This approval was granted in January, 1960, and work has started on the Culham site. The first building to be erected will be for I.C.S.E. and its associated facilities ; these are scheduled for completion during 1961. Further buildings will follow to accommodate the remainder of the research

and supporting services to be moved from A.E.R.E., Harwell, and a small team from A.W.R.E., Aldermaston, so that within four or five years the new laboratories at Culham should approach their planned size of 1000 total staff.

Changes in Membership of the Atomic Energy Authority

Lord Plowden relinquished his appointment as chairman of the Authority on December 31, 1959. He was succeeded by Sir Roger Makins. Sir Ivan Stedeford relinquished his appointment as a part-time member on July 31, 1959.

The Atomic Energy Authority Act, 1959, increased the permitted membership of the Authority from eleven to sixteen. Sir Leonard Owen was appointed Member for Production and Sir Claude Pelly Member for Weapons Research and Development. Both appointments were effective from January 1, 1960.

Electronic Control of Road Vehicles

Last week a lecture entitled "Some Steps Towards a System of Electronic Vehicle Control" was given at the Road Research Laboratory at Langley by Mr. L. E. Flory of the Radio Corporation of America. Mr. Flory explained the system which is being developed by the R.C.A. at its laboratories at Princeton, New Jersey. Part of his lecture is reproduced here.

A SINGLE lane of traffic with no passing requires only two functions from a driver. First, he must stay in his lane, and second, he must be prevented from colliding with the car in front of him. In this over-simplified situation, if we provide automatically for keeping a car in its lane and for preventing collision with a car ahead under any conditions, we have the elements of a complete control system. One more operational requirement must be met, viz. any system must be capable of being introduced gradually and must at all stages be compatible with existing traffic.

Consider a system which could be developed in three stages. First, a stage of improved communication with the driver to enable him to make decisions better and faster. Second, a stage where some of the decisions are made for him, and he is given a warning if he is approaching a dangerous condition ; and third, a final stage where the system actually takes physical control of the car either on a continuous basis or only if the driver failed to respond properly to the warning system.

It is obvious that to accomplish lane guidance there must be some interaction between the vehicle and the highway lane, by laying down in or on the roadway a trail which a vehicle can follow. The most direct method is the insertion of a cable carrying an alternating current down the centre of the lane. Simple detectors mounted on the car then provide control signals to the steering mechanism which will keep the car centred over the wire. This method permits the use of different frequencies for different lanes and route selection by change in frequency.

Collision prevention is a much more complex matter since it involves the interaction of two vehicles moving independently, only one of which can be assumed to have any special equipment. This situation suggests that the road must be the agent for transmitting a signal from the lead car, which may or may not be equipped with control devices, to the following car which is considered to be electronically controlled. Thus, the active source of the warning signal indicating the presence of the lead car must be within the road since a perfectly passive vehicle must make its presence and speed known to any equipped car following it. The road installation for collision prevention has thus the joint function of detecting vehicles at any point along the road, and of generating warning signals over a prescribed distance of road behind every detected vehicle.

Detection in the R.C.A. system is by a continuous sequence of wire loops embedded in the surface of the highway. The loops are about the size of a car and spaced only a few feet apart. As a vehicle passes over any loop the inductance of the loop is altered by the metal of the vehicle. This change is detected by an electronic circuit placed alongside the road.

In response to the action of the detector, a "flying tail" of electrical voltages is generated in the roadside circuits behind every detected vehicle. These voltages decrease in amplitude with the distance behind the vehicle. In the first stages of introduction of the system a tail of warning lights would be lighted in response to these voltages so that the driver of a following car would know that there was a car ahead. Different colours or patterns of lights could be used to indicate headway. By introducing a pattern into the series, motion of the lead car could be observed by the following car and his speed adjusted accordingly. Such a system might be installed immediately in areas of poor visibility.

In the second and third phases of the system, the roadside voltages would be used to activate transmitting equipment, which would generate a "flying tail" of the electromagnetic radiation which would carry the information concerning headway as well as a signal representing the speed of the leading car. These signals would be picked up by receiving equipment in the following equipped car, and the information regarding headway and speed extracted. In the second phase, this information would be used to sound warning signals or activate visual signals when either headway or closing speed approached a dangerous condition. In addition, pickup equipment could receive a signal from the guidance cable and sound a warning if the driver strayed from his proper position in the lane.

In the third phase, the received signals would operate the mechanical controls of steering, acceleration, and braking in a manner which would be predetermined by the design and adjustment of the control equipment in the car.

The Control System

The most conspicuous element of the detection system is the sequence of rectangular loops, comparable to a car in size, which are inserted into the pavement and form part of detection circuits whose active components are buried in capsules by the side of the road. The loops can then be installed quite simply in the roadbed during construction and have been installed in existing pavement by a simple and rapid diamond saw technique.

The loops are excited by a high-frequency current. When a vehicle passes over a loop it changes the inductance. This change in inductance causes a shift in the phase of the loop current which operates the phase sensitive detector unit. The unit in turn applies a gating potential to a signal generating unit which impresses a warning signal upon its associated antenna. Connecting all of the signal generators is a continuous one-way attenuating cable system. Thus, when a detector unit applies a gating potential to its immediately associated warning signal generator, it likewise impresses on all other generators a potential which decreases in magnitude exponentially as the distance from the car increases. This potential is used as a modulating signal by the generators to produce a warning signal which transmits distance information to the following car. The same decreasing potential can be used to operate visual warning lights which change in colour or pattern with distance.

An additional pulsed signal is impressed on the antennas within the tail each time a car moves from one detector to the next.

A following car picks up the warning signal which contains headway information ; in addition it receives a pulse each time the lead car crosses a detector. By making a measurement of the time between these pulses a measure of the speed of the car is obtained. The detectors themselves are relatively simple, as they must be since they must be repeated many times for each lane of the highway. The tail signal generators are likewise relatively simple.

It must be stressed that the equipment in the vehicle generates no signal. A vehicle influences following vehicles only through its presence acting through the detectors to modify the signals radiated by the antennas buried in the road to the rear of the vehicle. It follows that the flying tail of warning signals, indicating both distance and speed will be formed behind any car regardless of its equipment or the volition of the driver. Only the controlled car need contain any equipment.

The warning signal detector consists essentially of an antenna attached to the undercarriage of the car and a receiver whose output contains the distance and speed information relative to a car ahead. This output can then be used in conjunction with the speed of the car itself to operate warning buzzers or lights, and, in a fully automatic system, the brakes and the accelerator of the car. Automatic gain control makes the output signal independent of precise location of the detecting antenna relative to the antenna in the road and makes it dependent only upon the modulation of the signal. Complete absence of a signal as in a power failure will be correctly interpreted by the car as an emergency and the car will be brought to a stop.

In experimental installations the guidance signal has been obtained from two tuned antennas mounted on the left and right sides of the front bumper. As the car deviates to the right or to the left from the centre of the lane, the current induced by the field of the guidance cable in the left antenna comes to exceed that induced in the right antenna and vice versa. The difference in the rectified signals from the two antennas may operate an indicator in the car or, acting through a hydraulic system upon the steering mechanism, tends to maintain a balanced condition

with the car centred over the cable. Thus, with properly stabilised servo controls, the car proceeds down the centre of the lane without wavering unless the driver takes deliberate action to override the controls.

Consider now how the collision-prevention system operates. The accelerator and braking control mechanism of a controlled car guided down its lane must be governed by three factors. These are its distance from a car ahead, the speed of the car ahead, and its own speed. From these three items of information, a simple computer operation can decide whether the car should proceed, slow down, or stop.

An approaching car equipped to receive the warning signal will pick it up and will respond to it at a distance depending upon the operating threshold of its receiver. If this threshold is made to vary with the speed of the car, the critical distance, similarly, depends on this speed. The information coded into the warning signal is an indication of the distance to the leading car. As the lead car passes from one loop to the next, a pulse is put into the system. These pulses are also transmitted as a warning signal to the following car where the time between pulses is interpreted as the speed of the lead car. The computing mechanism in the car is adjusted so that the tail signal cannot reach a value higher than a certain level based on the speed of the car. If the signal tends to increase further, indicating too close an approach, the computer acts on the accelerator or applies the brakes to keep the signal at the predetermined level. The degree of action taken is determined by the closing speed, which is obtained from the speeds of the leading and following car.

There are a number of secondary benefits which might be derived from the adoption of the system. Thus, the existence of high-frequency carrier currents in the guidance cable and warning antennas permits voice communication from the highway control stations to the driver without any addition to the road installation. In this manner, the driver may be informed of route numbers, destinations, and other pertinent information as he approaches an intersection. Warnings with respect to weather changes, unfavourable road conditions, and hazards along the route may contribute to traffic safety. Voice communication may also be used to transmit important news flashes and emergency orders and, eventually, even information regarding commercial facilities in the area.

There are also a number of uses to which the detection system could be put immediately, on both throughways and secondary roads, without awaiting a full-scale road installation. Thus, the detectors may double in duty as traffic counters and speed controllers.

Engineers at the New York Port Authority are using the detectors in experimental traffic control problems at both the Lincoln and Holland tunnels. One manufacturer is marketing an automatic factory truck operating on the principles described ; it is feasible to design an almost completely automatic warehouse with provision for collecting material from storage and loading it upon trucks in accordance with a programme prepared in advance and fed into the system.

Future Developments

The principles of electronic guidance and collision-prevention were shown with a model car as early as 1953 ; the first full-scale demonstration of the basic elements of the system was given in 1957, at an installation on a 300ft section of a newly constructed intersection in Lincoln, Nebraska. The demonstration covered operation of the detectors with buried loops, the tail warning system employing both lights and radio signals, and the guidance system. Dashboard indicators permitted a manually-controlled car to be kept safely in the centre of the lane, adjusting its speed to that of a preceding vehicle even with the windshield completely blocked to simulate automatic control.

The guidance system alone has more recently been tested by the General Motors Corporation on a full-scale test track in Warren, Michigan, " to take signals like those of R.C.A. from the road and put them through specially designed equipment to steer a car." Chevrolet cars were operated at normal driving speeds. Signals were derived from two antennas on the front of the car. The difference signal was applied along with car speed and a signal indicating orientation of the front wheels to a computer. The output of the computer actuated the hydraulic steering cylinder through an electro-hydraulic servo valve. Considerable information was obtained as well as a great deal of confidence in the feasibility of automatic steering.

In our own laboratory we have been continuing with the study of the electronic techniques of the system. We are well aware that the operational problems are ill defined and to go too far in the development of details of the system without a clearer understanding of these problems would be folly. However, a great deal can be learned about the application of electronic techniques to our simplified situation of a single lane of traffic with no interference.

We have constructed a test lane, elliptical in shape with a perimeter of about a quarter of a mile, and equipped with all of the electronics necessary to generate the signals for complete control of a single lane of vehicles. Steering cable, detector loops, speed and distance antennas are all imbedded in the road surface. Electronic circuitry is contained in the boxes alongside the road. In an actual installation these circuits would be buried in the roadside. Circuits are provided to transmit distance and car-ahead speed to a following car. In addition, a pattern of lights can be generated following any car for the benefit of cars with no equipment.

In the portions of the system dealing with the actual control of the cars we have had co-operation of the General Motors Research Laboratories. They have furnished us with two cars equipped with steering control and with servo-operated brakes and accelerator. The steering equipment is that described for the earlier tests by General Motors. At speeds up to the design maximum of our track, steering is very good. At higher speeds, some anticipatory information would be highly desirable on moderately sharp curves. This, of course, can be built into the road by properly placing the cable with respect to the road centre so turning information is given to the car before it actually reaches the curve.

The warning signals carrying speed and distance information consist of two audio frequency signals of 4·5 and 8 kc/s respectively. One of these signals (4·5 kc/s) is pulse modulated in such a way that the length of the pulse varies directly with the distance from the lead car. The receiver in the controlled car decodes this information and feeds a voltage representing this distance to a simple computer. Another channel in the receiver responds to the pulse signal produced as the lead car passes from one detector to the next. The time between these pulses is measured and interpreted as the speed of the lead car. A voltage representing this speed is also fed into the computer as is the speed of the controlled car. The response of the controlled car is caused by this computer to follow a predetermined pattern, adapting its action to the existing conditions. The system is arranged so that absence of any signal is interpreted as a dangerous condition. For example, complete absence of a signal in the distance measuring receiver indicates a car dangerously close ahead while the absence of any speed information indicates a stopped car. These two conditions occurring simultaneously indicate the most dangerous possible conditions ; a stopped car immediately ahead. This is an example of the type of fail-safe feature which must be built into the system.

The two car system has been in operation for several months with quite impressive results. Control is complete and smooth even on emergency stops. There are many limitations in the system, however, which must be resolved before complete control could be remotely considered for actual highway use, and much more testing must be done with conditions more nearly approaching the open highway. In the meantime we are confident that limited electronic aids to the driver could be introduced immediately in the form of improved control at intersections, visual warning in fog and areas of poor visibility, and traffic actuated speed warning systems.

The Vehicle: Instrument of Land Usage

Mr. Patrick Horsburgh, A.R.I.B.A., A.M.T.P.I., Director of the Hamilton-Wentworth Area Planning Board, Ontario, who will be remembered in this country for his work on Barbican Scheme No. 1 and earlier on High Paddington, chose " The Vehicle : Instrument of Land Usage" as the title of a paper he read on July 18 at the Caxton Hall in London. The occasion was a meeting of the Railway Conversion League.

Mr. Horsburgh's paper was, in effect, a plea for the recognition of transport as a vital subject for study in the training of planners. A decade of active experience in urban, area and regional planning had convinced him that the void of ignorance between planners and transport engineers will become an ever greater hindrance to the improvement of our economic position. Mass movement and domestic tranquillity need not be incompatible nor economically unobtainable. Current technology is able to provide the means ; the vision of the planner and the determination of the politician must be kindled simultaneously.

Of recent years the emphasis has been predominantly on the provision of accommodation, with the result that accessibility has now become too large a factor in determining the value of property ; the pendulum must swing—though not too far—towards the provision of mobility ; planners should be trained to ensure that there is a proper balance between the statics of architecture and the dynamics of transport. Accordingly, the programme of study for planners, after their primary training in landscape comprehension, should include four equal and complementary courses in regional planning, urban planning, architecture and transportation. In Toronto the first steps are being taken towards the establishing of a Chair of Transport Studies, and this had encouraged Mr. Horsburgh to foresee the time when architecture will have been rightly supplanted by transportation as the parent subject of planning courses.

Mr. Horsburgh declared his belief in the conversion of this country's railway system into a motor road system as the greatest opportunity for re-development that has occurred since those same railways came into being a century ago. In ten years he had neither seen nor read anything to raise doubts in his mind upon the rightness of the stand the Railway Conversion League is making.

THE ENGINEER

Technical Contributors Section

JULY 1960

Tests on Eccentrically Loaded Riveted Joints

By PROFESSOR A. J. FRANCIS* and G. L. BELCHER

Tests to failure are described on fifteen riveted joints in which 0·080in 24ST Alclad aluminium alloy plates were connected by a group of twenty-four $\frac{1}{8}$in diameter 17ST rivets. The load was statically applied with initial eccentricities varying from 10in to zero. The strengths obtained were, on the average, 55 per cent in excess of the strengths calculated by the usual procedure for eccentrically loaded splices, but only 3·6 per cent below the strengths predicted by a theory which makes allowance for the development of plasticity in plates and rivets. It is suggested that such joints be designed on the basis of the proposed theory rather than by the conventional procedure.

IN an earlier paper[1] by the senior author (A. J. Francis) experiments were described on aluminium alloy riveted splices subjected to eccentric loading. The splices consisted of main plates riveted to two cover plates by three, four or nine rivets. The great majority failed at loads much greater than conventional calculations indicated, irrespective of whether failure occurred by shear of the rivets or by tearing of the plates; some of the nine rivet splices were stronger by nearly 50 per cent.

The increased strength was explained by a theory which takes account of the plasticity that must develop in rivets or plates before failure. The splices, however, contained relatively few rivets and were not designed for equal strength in rivets and plates.

Some doubt was felt as to whether the theory would be satisfactory for larger groups of rivets more nearly representative of practical splices, and for well-balanced joints in which rivets and plates both develop some plasticity before failure occurs in either. The present paper gives the results of tests on a series of splices with $\frac{1}{8}$in 17ST rivets, designed to meet both the above requirements.

Part I of the paper recapitulates the theory and Part II is an account of the experimental work, with the conclusions reached.

I. Theoretical Investigation

For completeness, the theory developed earlier[2] is here recapitulated briefly.

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Failure in the Rivets.—In the conventional design of a riveted splice under axial load it is assumed that the rivets share the load equally. This is true of such joints when shear failure of the rivets is imminent[3] (provided the joint is not exceptionally long) although at working loads the partition of load among the rivets is far from uniform. Thus, although such joints are apparently designed on a stress basis, the shearing stress in the rivets being limited to some fraction of the shearing strength, the basis of design is one of ultimate strength and the nominal stress factor of safety is the true factor of safety or load factor—

$$\left(=\frac{\text{ultimate strength}}{\text{working load}}\right).$$

In a splice subjected to a load which, while lying in the plane of the splice, is eccentric to the centroid of the rivet group, the load is replaced by an equal, parallel load through the centroid together with a couple. In designing such a splice it is conventionally assumed that, as in a joint under axial load, this parallel load is shared equally by all rivets.

The force on any rivet due to the couple, however, is assumed to act at right angles to the line joining the rivet to the centroid of the rivet group and to be proportional to the distance between the rivet and the centroid. This assumption can only be true for elastic rivets, which are so flexible compared with the plates that the latter can be regarded as rigid.[4] Evidently, where the rivets have a reasonable plastic range of shear deformation, the rivet loads become more nearly uniform than this before failure, and as in other statically indeterminate arrangements, the actual ultimate strength is greater, owing to plastic yield, than that indicated by the assumption of elastic behaviour. The comparison between actual and conventional (i.e. "elastic") strength is similar to that in a beam of rectangular section subjected to bending and axial force. In the absence of axial force the plastic moment of resistance is 50 per cent greater than the yield moment (at which yield begins in the outermost fibres); with small axial forces this percentage rises still further but reduces to zero when the axial force alone is sufficient to cause yielding over the whole cross section, without bending moment.

In a joint which is about to fail by shearing of the rivets, some at least of the rivets are in the plastic range of shear deformation and one or more are about to reach their ultimate shear deformation. It is reasonable to assume here that, as a first approximation, the deformation of the plates can be ignored in comparison with that of the rivets. This will obviously be admissible where the joint is much stronger in the plates than in the rivets, but even in a joint designed to have equal strength in plates and rivets it may not lead to much error, though there may be considerable plastic yield in the plates at rivet failure.

On this assumption the calculation of the strength of the rivets in an eccentrically loaded joint is simple once the load/deformation curve for a rivet is known. The shear deformation of a rivet as measured is partly due to shear and bearing deformation in the rivet shank and partly to bearing deformation in the plates around the rivet, and a means of measuring it, suggested by Vogt,[5] is described in the earlier paper referred to.

As a simple example consider the joint

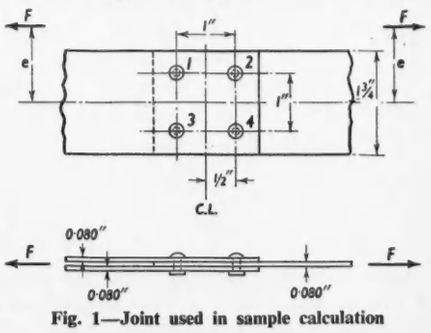


Fig. 1—Joint used in sample calculation

shown in Fig. 1, and let the average load/deformation curve for a single rivet be as shown in Fig. 9. Let the joint be subjected to a load F acting at an eccentricity e, and suppose that the joint is at the point of failure under this load. By symmetry, relative rotation of the plates will occur about some point A on the transverse centreline of the joint (Fig. 2 (*a*)), and the resultant deformation of each rivet can be broken down into an amount a in the axial direction (Fig. 2 (*a*)), and a deformation due to the

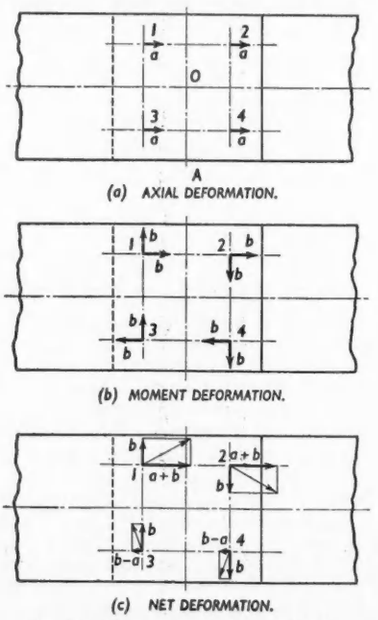
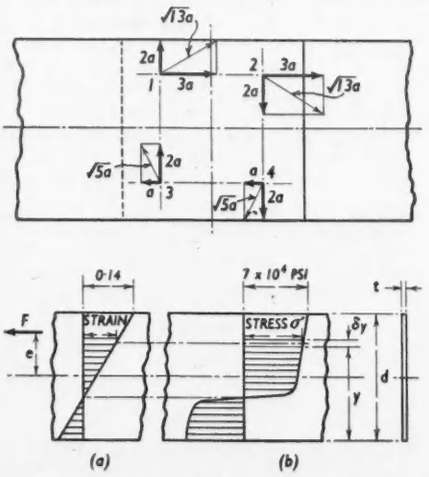


Fig. 2—Deformation of rivets at failure

moment at right angles to the line joining the rivet to the centroid O and proportional to the length of this line (Fig. 2 (*b*)). This latter deformation can be further broken down into components b_x and b_y parallel to and perpendicular to the longitudinal axis of the joint. In the particular joint chosen, all such deformations are the same owing to the geometry of the rivet pattern and will be denoted by b. The a and b deformations are then compounded to give the resultant deformation.

a and b are not known, but if we assume relative values for them we can work back and obtain the values of F and e. Thus, if we let $b/a=2$, Fig. 3 gives the resultant deformations in terms of a. Now if the two equally heavily deformed rivets (i.e. 1 and 2) are at the point of failure, their



Figs. 3, 4 (*a*) and 4 (*b*)—Strain and stress distribution across member

deformation must be equal to 0·022in, corresponding to the ultimate load of 955 lb (see Fig. 9). The deformation of rivets 3 and 4 is therefore equal to $0{\cdot}022\times\sqrt{5/13}$in, or 0·0136in, so that the load on these rivets is 925 lb.

The directions of the loads on the various rivets being known, F and Fe may be calculated by resolving longitudinally and taking moments about the centroid O. Thus

$$F=2{\cdot}955\,.\,\frac{3}{\sqrt{13}}-2{\cdot}925\,.\,\frac{1}{\sqrt{5}}=762\text{ lb} \quad . \quad . \quad . \quad . \quad . \quad (1)$$

$$Fe=2{\cdot}955\,.\,\frac{2}{\sqrt{13}}\,.\,\frac{1}{2}+2{\cdot}955\,.\,\frac{3}{\sqrt{13}}\,.\,\frac{1}{2}+2{\cdot}925\,.\,\frac{1}{\sqrt{5}}\,.\,\frac{1}{2}+2{\cdot}925\,.\,\frac{2}{\sqrt{5}}\,.\,\frac{1}{2}$$

$$=2567\text{ lb in} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

Hence

$$e=\frac{2567}{762}=3{\cdot}37\text{in} \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

By contrast, in the conventional calculation of the strength of this joint for the case shown in Fig. 3, the vectors would be forces, not deformations, $\sqrt{13}\,a$ representing the ultimate load of 955 lb and the other vectors representing loads in proportion to their lengths. This would give the following values :

$$F=1058\text{ lb} \qquad e=2\text{in}$$

The two results are not immediately comparable, but when a complete range of values is worked out the difference in ultimate and conventional strengths is at once obvious.

If the load/deformation curve for the rivets is not known, an approximate estimate of the strength (it is in fact an overestimate) may be made by assuming that all rivets, regardless of their deformations, reach the ultimate load of 955 lb when failure occurs. Curve (*b*) for the rivets in Fig. 10 is based on this idealised behaviour.

Failure in the Plates.—The conventional design of the connected members in eccentric splices is also conservative in that the strength is calculated on the assumption of an elastic distribution of stress across the members at their most critical sections.

If the stress-strain relationship for the material of the members is known, the actual strength may be calculated on the assumption that fracture of the tensile edge occurs when the ultimate tensile strain is reached. Let the average relationship be as in Fig. 7, with an ultimate strain of 0·14. Assuming that plane sections remain plane, and that the longitudinal fibres of the material in the members behave in tension and compression exactly as in the tensile test specimen, we may take any linear strain distribution (Fig. 4 (*a*)) having the ultimate value at one edge, and obtain from it, by reference to the stress-strain curve, the stress distribution (Fig. 4 (*b*)). Then

$$F=\int_0^d \sigma t\,dy$$

$$F(e+d/2)=\int_0^d \sigma t y\,dy$$

for the particular case of a plate. The integrations are performed graphically, allowance being made for the presence of rivet holes, and F and e are obtained. By selecting a number of different strain distributions sufficient values of F and e may be derived to construct a curve relating the two variables.

Since the actual strain distribution across the critical section is likely to be affected by the presence of heavily loaded rivets in the rivet holes, the plate strength given by the above method is likely to be a little over-optimistic.

When the stress-strain characteristics of the material are not known, the strength may be estimated on the assumption that the material is ideally rigid-plastic. Curve (*b*) for the plates in Fig. 10 is based on this assumption.

II. Experimental Investigation

Description of Test Specimens.—In order to verify the theory outlined in Part II for joints with larger rivet groups than had previously been investigated, tests were carried out on fifteen twenty-four-rivet specimen joints (Fig. 5).

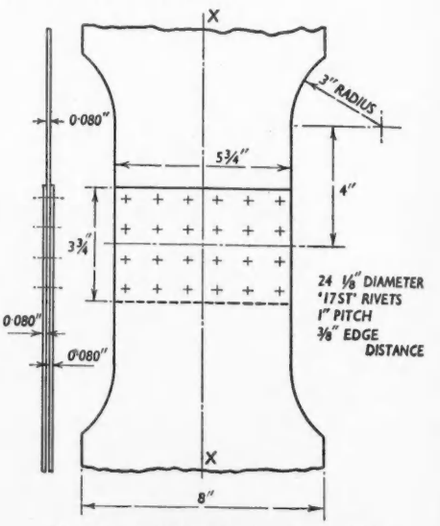


Fig. 5—Twenty-four-rivet specimen joint

The plates were from 0·080in thick 24ST Alclad aluminium alloy sheet, cut so that the longitudinal axis coincided with the direction of rolling. The rivets were $\frac{1}{8}$in diameter 17ST aluminium alloy rivets to specification AN470, as used by the Commonwealth Aircraft Corporation, Melbourne.

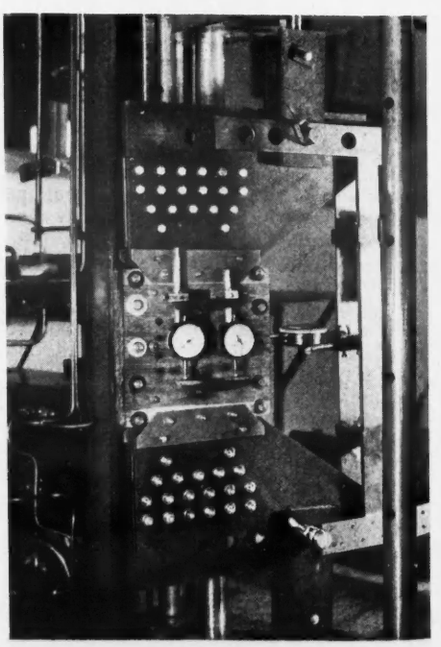


Fig. 6—Specimen in testing machine

The rivet holes were drilled No. 30 (0·128in). The rivets were all from the same batch, and were driven by normal hand-operated hammer at the Corporation's factory.

The specimens were provided with end fittings (see Fig. 6) through which it was possible to apply a longitudinal tensile load in the plane of the specimen either along the axis *XX* (Fig. 5), or parallel to it with an initial eccentricity of 2in, 4in, 7in or 10in.

Tests on Specimens of Plate and on Single Rivets.—It was desirable that each specimen should, as far as feasible, be equally strong in rivets and sheet, as this represents good design practice. From the description of the theory outlined in Part I it will be realised that before the joints could be designed it was necessary to know the mean stress-strain curve for the sheet and the mean load-deformation curve for the rivets.

(*a*) *Stress-Strain Curve for Sheet.*—This was determined from three tensile specimens cut from the sheet from which the joints were later fabricated. Strains were measured on a 2in gauge-length with a Robin extensometer. This had a limited range and its use was discontinued at a strain of 0·016. The stress-strain curve was extrapolated to a strain of 0·040. It was assumed that the stress-strain curve was linear between the strain of 0·040 and the ultimate strain measured on the specimen after fracture. Fig. 7 shows the mean stress-strain curve obtained. (The true curve is more likely to be of the form shown by the dotted line in Fig. 7.)

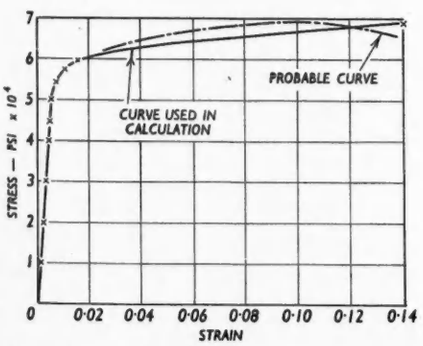


Fig. 7—Average stress-strain curve for plate material

It was assumed that the stress-strain relationship for the material was the same in compression as in tension.

(*b*) *Load-Deformation Curve for a Single Rivet.*—This was measured on twelve specimens made to the dimensions shown in Fig. 8. The rivets were from the same batch as those used in the large joints and were driven in the same way. Deformations were measured by means of a simple dial gauge extensometer on a 1in gauge length between the free ends of cover and main plates (Fig. 8); this procedure ensured that the part of the deformation due to compression of the plates near the rivet, as well as that due to shear and bending of the rivet shank, was recorded.[5] Great care was taken to record the deformation at failure as accurately as possible. Fig. 9 shows the average curve obtained and also the upper and lower boundaries of the experimental points (broken lines). There was a good deal of scatter of the curves, the strength varying between 830 lb and 1060 lb (average 955 lb) and the deformation at failure between 0·0205in and 0·0283in (average 0·022in), excluding one exceptionally low value.

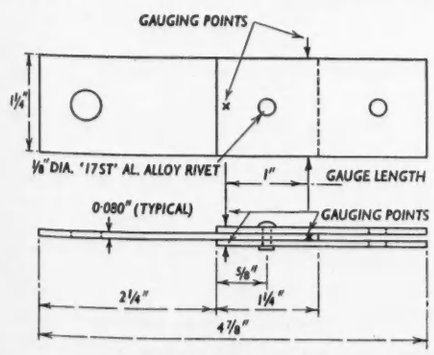


Fig. 8—Single rivet specimen

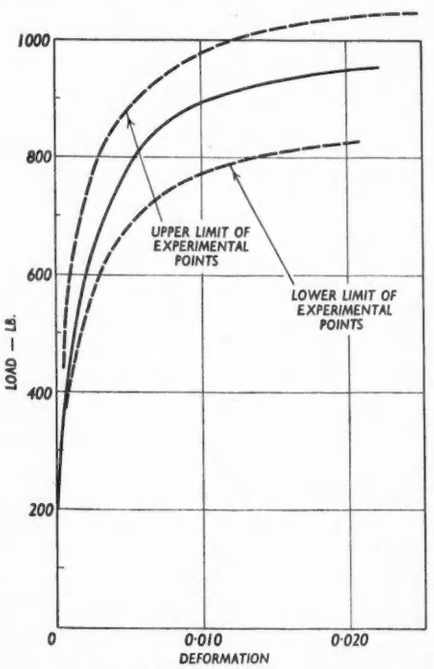


Fig. 9—Average load-deformation curve for single rivet

Design of Multi-Rivet Specimens.—By trial and error, joint dimensions were arrived at (Fig. 5) which gave nearly equal plastic strength in rivets and central plate under tensile load applied over the whole range of eccentricity 0in to 10in, the strength being calculated by the methods outlined in Part I. The plate and rivet strengths calculated on the basis of conventional design were also found to be closely similar. Table I and Fig. 10 give the results of these calculations.

The results are also presented in the form of an interaction curve (Fig. 11). In this diagram M is the actual moment at failure and M_p the moment the joint would carry at infinite eccentricity (i.e. with zero axial load), F is the actual axial load and F_p the axial load at zero eccentricity. The predicted and conventional curves are shown. The predicted curve is calculated from the experimentally determined characteristics of plates and rivets, only the lower strength (mainly in the plates except at low eccentricities) being shown, thus giving a single strength curve.

Tests on Multi-Rivet Specimens.—Three specimens were tested in the A.R.L. 30,000 lb testing machine at each initial loading eccentricity (0in, 2in, 4in, 7in and 10in), the load in each case being increased by small increments until failure occurred either by fracture of the plate or shear of the rivets.

The following measurements were recorded at each value of the load :

(*a*) *Reduction in Eccentricity.*—The eccentricity of load was measured by a dial gauge which registered against the tension edge of the specimen and which was supported by a

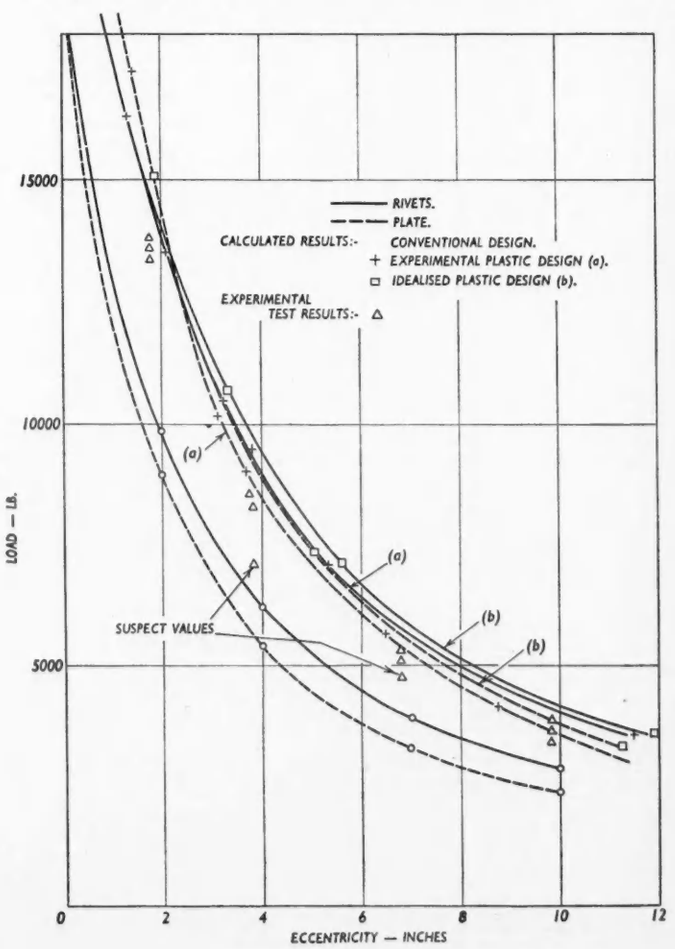


Fig. 10—Load-eccentricity curves for test specimens

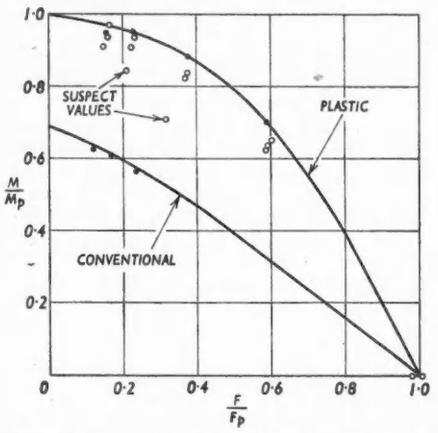


Fig. 11—Interaction curve for twenty-four-rivet joint

framework located by the loading pins of the testing machine.

Particular care was taken to record the eccentricity of load at failure. The accuracy of measurement was about ±0·010in, and was governed mainly by the initial measurement, made with steel rule and straight-edge.

(*b*) *Overall Axial Elongation and Angular Rotation.*—These were measured by fourdial gauges attached to the main plate, two on each face of the specimen, on a longitudinal gauge length of 4·8in and a lateral gauge length of 3in (Fig. 12). Each pair of dial gauges registered against a fitting which was attached to the cover plate on that side of the

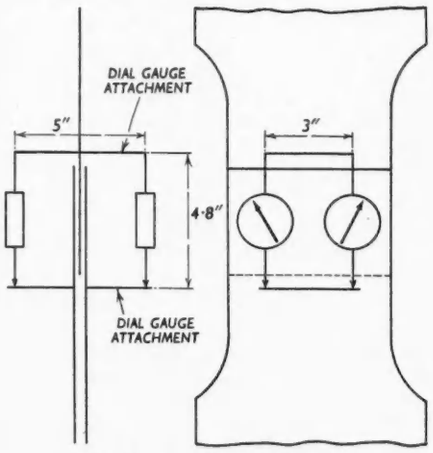


Fig. 12—Location of dial gauges

specimen. The elongation of the joint was taken as one-quarter of the sum of the dial gauge extensions and the rotation of the joint as one-half of the sum of the rotations of each cover plate relative to the main plate.

The individual dial gauge readings from which the extension and rotation measurements were derived were accurate to probable limits of ±0·0005in in the low load range. At loads near the failing load an added systematic error of 0·0010in occurred between the reading of the first and last gauges owing to the creeping of the specimen under constant load.

Before the tests were carried out it was realised that it would be difficult to prevent local or overall buckling of the compression edges of the plates. Experiments were therefore made on a specimen made for this purpose, as the result of which the cover plates were each made the same thickness as the main plate instead of half this thickness, as was the original intention. In addition, the compression edge was stabilised with a pack clamp which consisted of two pieces of hardwood 9in by 9in by $\frac{7}{8}$in, bolted around the specimen (Fig. 6). The wood was drilled to accommodate the heads and tails of the rivets and the gauge fittings, and was inserted with a steel strip in order to give good support to the compression edge of the specimen.

The bolts which fastened the pack clamp together were tightened to the same torque prior to each test. The frictional loads due to the effect of the pack clamp were determined by conducting tests on a non-riveted specimen. The average frictional load was 3·2 per cent of the expected failing load at 0in eccentricity and 3·7 per cent at 10in eccentricity, the error in the frictional load being 0·5 per cent of the failing load at 0in eccentricity and 2·7 per cent at 10in eccentricity.

Experimental Results.—The failing loads of the specimens are recorded in Table I and are plotted in Fig. 10 against eccentricity of load at failure, and in Fig. 11. Figs. 13 and 14 show the axial elongation and angular rotation respectively, plotted against load. In all cases the measured load was corrected for the effect of friction due to the clamp by deducting the estimated frictional load.

All gauges behaved irregularly at very low loads. The irregularity in the gauge recording the eccentricity was due to an alteration in the position of the dial gauge supporting framework relative to the specimen as the initial load was applied, owing to the clearance fits of the loading pins in the end fittings of the specimens and the frame carrying the gauge. The magnitude of this error was estimated by extrapolation of the eccentricity dial gauge readings back to zero load, and these corrections, which were of the order of 0·010in, were incorporated in the final readings.

Discussion of Results.—It will be seen from Table I and Figs. 10 and 11 that the calculated strengths of the specimens, (*a*) using the actual load-deformation characteristics of rivets and plate, and (*b*) assuming idealised behaviour in rivets and plate, did not differ greatly. Values (*b*) were in excess of values (*a*), but only by a few per cent on the average. On either basis of calculation the rivets were stronger than the plate except at eccentricities of 0in and 2in.

There was a remarkable difference between the strengths as calculated above and the conventional strengths, the latter being exceeded by roughly 55 per cent in the case

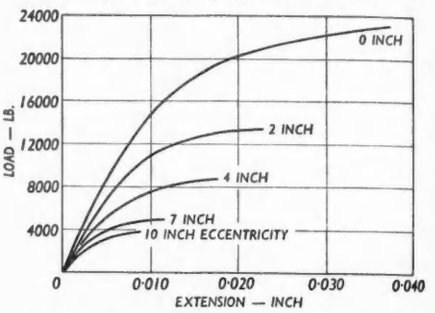


Fig. 13—Average axial extension versus load

of values (*a*) and about 62 per cent for values (*b*), except for the axially loaded specimens.

The actual strengths of the eccentrically loaded specimens, although on the average 5 per cent below the expected strengths on basis (*a*) were 52 per cent above the conventional failure loads. The average strength

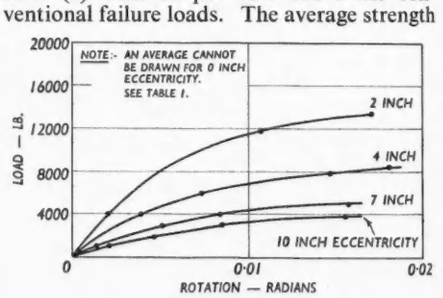


Fig. 14—Average rotation versus load

of the single rivet specimens agreed very closely with that of the rivets in the three multi-rivet specimens tested under axial load, the latter failing at loads which were 102, 100 and 98 per cent of that based on the single rivet values.

The mode of failure (i.e. rivets or plate) was in agreement with that predicted by the calculations except for two of the specimens tested at 2in eccentricity, but the estimated plate and rivet strengths at this eccentricity

TABLE I

Initial eccentricity (nominal)		10in			7in			4in			2in			0in		
Design loads, lb — Based on actual properties — Theoretical — Plate		3,650			5,200			8,500			13,700			27,800		
Design loads, lb — Based on actual properties — Theoretical — Rivets		3,920			5,450			9,050			13,600			22,920		
Design loads, lb — Idealised — Plate		3,750			5,300			9,000			14,500			27,800		
Design loads, lb — Idealised — Rivets		4,100			5,800			9,500			14,000			22,920		
Design loads, lb — Conventional — Plate		2,410			3,310			5,320			8,940			27,800		
Design loads, lb — Conventional — Rivets		2,910			3,965			6,206			9,896			22,920		
Load at failure (lb)	3,810	3,570	3,680	5,300	4,760	5,140	8,580	7,080	8,300	13,800	13,600	13,400	23,000	23,000	22,400
Eccentricity at failure (inch)	9·81	9·80	9·81	6·78	6·80	6·81	3·75	3·84	3·82	1·80	1·79	1·78	0·03	0	0
Type of failure : P–Plate ; R–Rivet	P	P	P	P	P	P	P	P	P	R	P	P	R	R	R
Expected failure load at failure eccentricity, lb	3,700	3,700	3,700	5,350	5,300	5,300	8,900	8,800	8,800	14,600	14,600	14,700	22,600	22,920	22,920
Failure load / Expected failure load	1·03	0·97	1·00	0·99	0·90	0·97	0·96	0·80	0·94	0·94	0·93	0·91	1·02	1·00	0·98
Failure load / Conventional design load	1·58	1·48	1·53	1·60	1·44	1·55	1·61	1·33	1·56	1·54	1·52	1·50	1·00	1·00	0·98
Extension at failure (inch)	0·010	0·007	0·006	0·011	0·010	0·012	0·019	—	0·017	—	0·020	0·023	0·033	0·037	0·041
Rotation at failure (radians)	0·015	0·019	0·013	0·017	0·012	0·017	0·018	—	0·018	—	0·013	0·019	−0·001	0·002	−0·002

were so nearly equal that complete agreement was not to be expected.

The specimens behaved consistently except that one of those tested at 4in eccentricity failed at 20 per cent less than the expected load. The reason for this exceptionally low strength is not known. It was thought that the rivet nearest the point where the plate fractured may have had unusually high strength and low ductility, and that this could have given rise to exceptional stress concentrations in the plate at this point. This rivet was therefore tested after removal from the specimen, but did not appear to have the suspected properties. Tests on two coupons cut from the plate material were also inconclusive, the plate material being up to normal strength. During the testing of this specimen a report was heard at a load of 5300 lb and the load dropped off slightly. It is possible that one of the rivets failed at this stage ; if this were so the resulting change in stress distribution across the plate might have led to the premature failure.

The second 7in specimen also failed at an unexpectedly low load. In this case it was probably due to failure of the testing machine to register correctly.

If the results of the tests on these two specimens be discarded as suspect, the ultimate strengths of the remaining eccentrically loaded specimens are on the average 55 per cent in excess of the conventional strengths and only 3·6 per cent below the predicted strengths.

III. Conclusions

There was reasonably close agreement within the limits of experimental error between the predicted strengths of the splices and the experimental values, if the two tests which were suspect are discarded. The predicted strengths were slightly greater than the test values. This is probably the result of the disturbance to the assumed linear strain distribution across the plates at the critical section, caused by the presence of heavily loaded rivets in the rivet holes.

It is recommended that eccentric joints of aluminium alloy be designed for static loading on the basis of the theory, using a suitable load factor, rather than by the conventional procedure which is over-conservative. A slightly greater load factor than would normally be adopted should be used to allow for the slight reduction in observed strengths below the predicted values.

References

[1] Francis, A. J., "The Behaviour of Aluminium Alloy Riveted Joints," Research Report No. 15, Aluminium Development Association, 1953.
[2] Ibid, pages 85–90.
[3] Ibid, page 91.
[4] Ibid, page 23.
[5] Vogt, F., "Load Distribution in Bolted or Riveted Joints in Light-Alloy Structures," U.S. Nat. Advis. Committee, Aero Tech. Memo. No. 1135.

Stiffness of a Crane Jib

By J. F. EDEN, B.Sc., M.I.Mech.E.,* and R. H. WOOD, D.Sc., Ph.D., A.M.I.C.E., A.M.I.Struct.E.*

The stiffness of the jib of a derricking crane, in a plane normal to the plane of luffing, depends on its effective length as a strut, and this is shown to depend on a simple ratio of dimensions determined by the angle of the jib and the position of the rope pulleys. A theoretical expression for the effective length is given and also the results of a number of buckling tests on a model jib. Where the two fixed pulleys are vertically over the jib pivot (as is usual in derrick cranes), the effective length of the jib is equal to its actual length and is independent of the angle of the jib. In all other cases the effective length varies with the angle of the jib and may be determined with a sufficient degree of accuracy for normal purposes from the approximate formula $l/L=2-C/A$ where l/L is the ratio of the effective length to the true length of the jib, C is the horizontal distance between jib head and jib foot, and A is a dimension determined by the horizontal distances between the jib head and the fixed pulleys over which pass the derricking rope and the hoist rope. The article goes on to discuss the normal way in which the effective length is used in the design of a strut such as a crane jib, as specified in B.S. 2573. An alternative method is suggested which deals more effectively with cases of combined bending and axial compression and can be applied with justification to latticed or battened struts which are very common in crane structures.

THE jib of a luffing crane may fail as a result of two predominantly different conditions. If it is a latticed jib, the shape of the structure as a whole may cause a weakness or, alternatively, the proportions of some individual member may be a primary cause of failure. Both conditions must be considered by the designer of the jib, and in a simplified design procedure this involves limiting working stresses to values which are selected in accordance with the slenderness ratio of the jib or members.

The method followed by British crane designers is given in British Standard 2573 : 1955, "Report on Permissible Stresses in Crane Structures," but neither this nor any of the British Standards for cranes yet deals specifically with the end conditions of the jib acting as a whole as a strut, which may vary according to its working position, and must be known in order to determine the "effective length," and thus the slenderness ratio l/r. In view of the similarity of this case to some of the more recent studies in "frame instability,"[1, 2] the investigation into this subject, which is reported below, has been extended to consider briefly the stability of a latticed strut which is both bent and compressed by external loads.

The aim of this note is to examine the buckling of the whole crane jib about either axis in turn, one axis representing an obvious and easy case, the other being much more difficult. A simple method of deriving the effective length of the jib having been found, the designer may then follow one of two courses. Either he may use this new information in conjunction with the present British Standard, or he may take note that the effective lengths so obtained refer in fact to a corresponding elastic buckling load for the whole jib, technically known as the "critical" load. Now a knowledge of this critical load provides him with a (conservative) magnification factor, by which to multiply any bending moments present in the jib, in order to take account of instability effects. This latter procedure leads to a type of design whereby the maximum stress in the crane jib can be examined on a logical basis, free from empirical rules. A worked example is given later.

Consider the crane jib AB shown diagrammatically in Fig. 1 (*a*). This is subjected to an axial thrust P, being the resultant of the load W, the tension T in the hoist rope ($T=W$ only when the single fall arrangement is used and friction in the jib head pulley is neglected), and the load KT applied to the jib head by the derricking rope. If buckling is considered in the plane of the paper (in the plane in which the jib luffs), it is clear that both ends of the jib are fixed in position but free to rotate, hence the critical load will be the same as the Euler load and the effective length $l=L$, if, for a first approximation, the jib is assumed to be of uniform section.

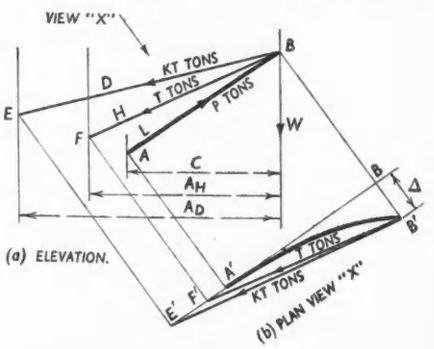


Fig. 1

The position as regards buckling in a plane normal to the plane of luffing is more complex. If, as in a ship's derrick, the jib is free to rotate in plan at the pivot A, both ends

List of Symbols

a—Distance of extreme fibre from neutral axis, inches.
A—See text and Fig. 3.
A_D—Horizontal distance (inches) between jib head and fixed pulley for derricking rope.
A_H—Horizontal distance (inches) between jib head and fixed pulley for hoist rope.
C—Horizontal distance (inches) between jib head and jib pivot.
D—Distance (inches) between jib pulley and fixed pulley for derricking rope (along line of rope).
e—Eccentricity due to "out-of-straightness," inches.
E—Modulus of elasticity, tons per square inch.
f—Combined stress due to bending and that due to the factorised axial load, tons per square inch.
f_2—Combined stress due to bending and that due to the axial working load, tons per square inch.
f_3—Extreme fibre stress in compression member of a latticed strut.
f_a—Working stress in axial compression, tons per square inch.
f_{bc}, f_{bt}[1]—Working stress in the extreme fibre due to bending compression, tons per square inch.
F_c—Maximum permissible stress in the extreme fibre, due to axial compression and bending, tons per square inch.
F_a—Maximum permissible axial stress in compression, tons per square inch.
F_{bc}—Maximum permissible extreme fibre stress due to bending compression, tons per square inch.
F_y—Yield stress, tons per square inch.
H—Distance in inches between jib head pulley and fixed pulley for hoist rope (along line of rope).
I—Moment of inertia of cross section of jib, inch units.
K—Ratio of load applied to jib head by derricking rope to that applied by the non-vertical part of the hoist rope.
K_2—Load factor.
KT—Load in tons applied to jib head by derricking rope.
k—Nominal stiffness of jib $=I/L$.
l—Effective length of jib in inches.
l_m—Effective length of compression member of a latticed strut, between bracings.
L—Length of jib (inches) between centres of pivot and jib head pulley.
M_A, M_B—End moments, see text and Fig. 2.
η—c_s/r^2, Perry's constant.
P—Axial thrust in jib, tons.
P_{crit}—Critical axial thrust in jib, tons.
P_E—Euler load for jib, tons $=\pi^2EI/L^2$.
r—Radius of gyration of cross section of jib, inches.
r_m—Radius of gyration of compression member of a latticed strut.
s, s'', c, n—Stability functions, see text.
T—Load applied to jib head by non-vertical part of hoist rope, tons.
W—Hook load, tons.
Z—Modulus of rigidity, cubic inches.
Δ—Lateral deflection at jib head, inches.
θ_A, θ_B—Lateral end rotation, radians.
θ—Angle of elevation of jib to horizontal, degrees.
ω_1, ω_2, ω_3—Magnification factors.

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can still be regarded as pin-jointed, with $l=L$. However, in any slewing crane the end A can be considered fixed and non-rotatable in plan. If the end B were restrained in position but free to rotate, the effective length could be taken as $l=0{\cdot}7L$, and if it were completely free the effective length would be $l=2L$. It can be seen from the plan view, Fig. 1 (*b*), that the actual conditions which obtain are between these two extremes. The jib head B is not fixed in position, but if it deflects to B' due to any accidental disturbance corresponding to an arbitrary sidesway of Δ, the hoist rope and the derrick rope take up positions $B'F'$ and $B'E'$ and the loads in them now have components in the plane of buckling which offer a degree of restraint to further deflection.

Thus, if Δ is small in relation to L, the small angles that the hoist rope and the derricking rope make with the original line of the jib are Δ/H and Δ/D respectively. Under such conditions the restoring force at right angles to the original line is

$$\frac{T\Delta}{H}+\frac{KT\Delta}{D}.$$

Until the critical load is reached, this force is sufficient to restore equilibrium in the jib when the instability effects associated with the direct load P in the jib and the sidesway Δ are taken into account. Beyond the critical load the overturning force due to instability exceeds the restoring force. Treating this view of the jib, for the purposes of simplified design, as analogous to a uniform cantilever, the problem of finding the critical load can be solved by recourse to tabulated instability functions, of which the best existing tabulation is that suggested by Professor W. Merchant and produced by Livesley and Chandler[3] of Manchester University. Thus, consider a strut AB, Fig. 2, acted upon by

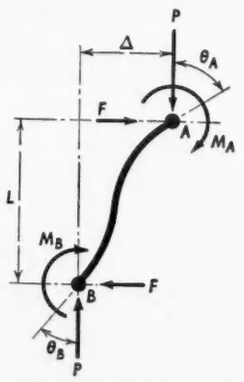


Fig. 2—Deflections of a strut acted upon by end moments and forces

end moments M_A and M_B (arbitrarily clockwise positive) and by end forces F (arbitrarily a clockwise overturning couple). Then if the strut is to be in equilibrium,

$$M_A+M_B+P\Delta+FL=0 \quad . \quad . \quad . \quad (1)$$

In our particular case the end forces are the restraining forces from the ropes and, therefore,

$$F=\frac{T\Delta}{H}+\frac{KT\Delta}{D} \quad . \quad . \quad . \quad . \quad (2)$$

Now the special feature of the stability functions is that, in the presence of a direct load, the well-known slope-deflection equations for beams can be neatly transformed by reforming the coefficients of the equations in terms of two stability functions s and c, where s signifies a modification of the stiffness and c a modification of the carry-over in a moment distribution process. Thus, one suitable general form is :

	Coefficients of			
	$Ek\theta_A$	$Ek\theta_B$	$Ek\Delta/L$	
$M_A=$	s	sc	$-s(1+c)$	. . . (3)
$M_B=$	sc	s	$-s(1+c)$	. . . (4)
$FL=$	$-s(1+c)$	$-s(1+c)$	$s^2(1-c^2)$	. . . (5)

Note k is nominal stiffness $=I/L$ of the strut.

It will be noticed that in general this forms a neat symmetrical matrix of coefficients for the three equilibrium equations (3), (4), (5). In our particular case the base of the strut is considered fixed (other solutions with partial degrees of fixity will not be considered here) so that $\theta_B=0$ say. In addition, there is no applied moment at the top, i.e. $M_A=0$ if the pulleys are assumed to be small in size. These two conditions applied to equation (3) lead straightway to :

$$\theta_A=(1+c)\Delta/L \quad . \quad . \quad . \quad . \quad (6)$$

Whence

$$FL=Ek\left[s^2(1-c^2)\frac{\Delta}{L}-s(1+c)^2\frac{\Delta}{L}\right]$$

$$=Ek\,.\,s(1-c^2)\left[s-\frac{1+c}{1-c}\right]\frac{\Delta}{L}$$

$$=Ek\,.\,s''[n]\frac{\Delta}{L} \quad . \quad . \quad . \quad . \quad . \quad . \quad (7)$$

where

$$s''=s(1-c^2) \text{ and } n=\left(s-\frac{1+c}{1-c}\right)$$

and are both conveniently tabulated by Livesley and Chandler, being functions of the ratio of the load in the strut to the Euler load :

$$P_E=\frac{\pi^2EI}{L^2}=\frac{\pi^2Ek}{L}.$$

From the tables it is noticed that $s''\,.\,n=0$ when $P/P_E=\frac{1}{4}$, which means that without additional restraint from the ropes ($F=0$) the deflection Δ may have any value and the jib would buckle at one-quarter of its Euler load, i.e. when its effective length was twice its actual length. Above this load $s''\,.\,n$ becomes negative, indicating that when restraint is provided the enhanced critical load is given by the condition :

$$0=\frac{Ek}{L}s''\,.\,n\frac{\Delta}{L}+\frac{T\Delta}{H}+\frac{KT\Delta}{D} \quad . \quad . \quad (8)$$

This is a statement that the restraining force from the ropes just balances the overturning force, and the particular thrust in the jib that will make this true is the " critical " load.

Noting that

$$\frac{Ek}{L}=\frac{P_E}{\pi^2}$$

we obtain for the critical condition :

$$\frac{T}{P_E}\cdot\frac{L}{H}+\frac{KT}{P_E}\cdot\frac{L}{D}=\frac{-s''\,.\,n}{\pi^2} \quad . \quad . \quad (8a)$$

where s'' and n depend upon P_{crit}/P_E for their values.

It is now necessary to find the thrust P in terms of the positions of the ropes. Thus, from the geometry of Fig. 1, resolving forces horizontally at point B and observing that whereas the hook load contributes towards the thrust, it does not affect the horizontal components, then :

$$\frac{PC}{L}=\frac{T\,.\,A_H}{H}+\frac{K\,.\,T\,.\,A_D}{D}$$

or

$$P=\frac{LT}{C}\cdot\frac{(A_HD+KA_DH)}{HD} \quad . \quad . \quad . \quad . \quad (9)$$

But

$$P_E=\frac{-\pi^2}{s''\,.\,n}\cdot\frac{LT(D+KH)}{HD} \text{ from (8}a\text{)}. \quad (10)$$

Hence, from (9) and (10),

$$\frac{P}{P_E}=\frac{-s''\,.\,n}{C\pi^2}\left(\frac{A_HD+KA_DH}{D+KH}\right) \quad . \quad . \quad . \quad (11)$$

In this expression, the term

$$\left(\frac{A_HD+KA_DH}{D+KH}\right)$$

can be shown by geometry to be the dimension A in Fig. 3, where V is the point where

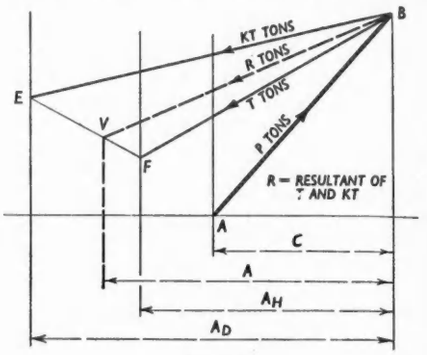


Fig. 3

the line VB of the resultant of the forces T and KT cuts the line EF joining the two fixed pulleys.

Thus, if we write

$$A=\left(\frac{A_HD+KA_DH}{D+KH}\right),$$

the critical equation becomes

$$\frac{P_{crit}}{P_E}=\frac{-s''n}{\pi^2}\cdot\frac{A}{C} \quad . \quad . \quad . \quad . \quad (12)$$

It can also be shown that the expression

$$\frac{-\pi^2P/P_E}{s''\,.\,n}$$

further simplifies to the value of $1-1/n$. This leads straightway to the critical condition that $1-1/n=A/C$, leading to

$$n=\frac{C/A}{C/A-1} \quad . \quad . \quad . \quad . \quad . \quad (13)$$

It will be seen that C/A is therefore the important ratio for determining critical loads: for this ratio straightway defines n, and the corresponding value of P_{crit}/P_E is obtained directly from tabulated values of n. The effective length is then defined by

$$l=L\sqrt{\frac{P_E}{P_{crit}}} \quad . \quad . \quad . \quad . \quad (14)$$

The theoretical curve resulting from the relationship (13) is shown as a full line in Fig. 4. It will be seen that it is very nearly a straight line between an effective length ratio of 2, occurring when $C/A=0$ (i.e. jib vertical or fixed pulleys at an infinite distance) and an effective length ratio of unity when $C/A=1$ (i.e. both fixed pulleys vertically above the jib pivot). Between these two values the effective length ratio will depend on the position of the fixed rope pulleys and the relative tensions in the two ropes. Thus if the hoist rope is unloaded ($T=0$), K becomes infinite, $1/K=0$ and $A=A_D$. Conversely, if the derricking rope has no tension, as might occur with the jib nearly vertical, $K=0$ and $A=A_H$. In both cases the problem reduces to a single rope and the projections in plan of the rope and the jib provide the all important ratio for finding the critical load in (12). Also, if in Fig. 1

the fixed pulleys for derricking rope and hoist rope are in one vertical line, then $A=A_H=A_D$.

Finally, if in Fig. 1 both fixed pulleys are vertically over the jib pivot $A_D=A_H=A=C$, so that $n=\infty$, which coincides with $P_{crit}/P_E=1$.

This means that the effective length of the jib is the actual length whenever the fixed

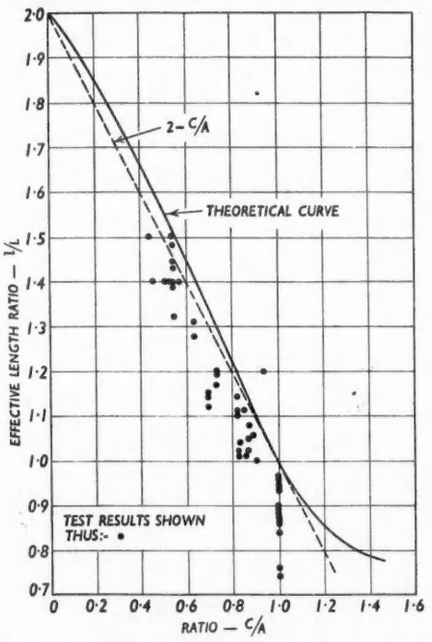


Fig. 4—Variation of effective length ratio with ratio C/A

pulleys for both ropes are vertically above the jib pivot. When this occurs, the ratio $C/A=1$ for all angles of elevation of the jib. This arrangement of the rope pulleys is therefore unique in giving a constant value of unity for the equivalent length of the jib in all positions.

The straight line shown dotted in Fig. 4, which closely approximates to the theoretical curve, can be expressed as $l/L=2-C/A$. This expression was given to the authors at an early stage in this investigation by Mr. S. Hall, of Joseph Booth and Brothers, Ltd., who derived the expression from purely geometrical considerations, making the assumptions that the strut bends in a circular arc and that the effective length is the length of a chord to the circle along the line of the resultant of the two rope tensions. This approximate expression is so much simpler that it will be preferred by most crane designers and it is safe to use providing that C/A does not exceed unity, i.e. so long as the fixed pulleys for the ropes are not in front of the jib pivot.

Model Tests

In order to verify the theoretical results, some fifty tests were carried out on a model shown in Fig. 5. The model jib consisted of a flexible high-tensile steel strip, 1in by 0·023in in section, fitted with small pulleys and a stirrup at the head to carry the hoist and derricking ropes respectively. At a distance of exactly 10in from the centre of the jib head pulleys, the strip was securely clamped to the head of a shaft mounted at right angles to the jib in rigid bearings, the clamping point corresponding with the axis of the shaft. A vertical back board mounted behind the jib was scribed with jib angles and contained a number of holes into which pegs could be inserted to anchor the ropes and simulate the position of fixed pulleys.

By definition, the critical load is the load at which an infinitely small disturbing force will cause infinite deflection. Each test was carried out as follows : A thread tied to the jib head was passed over a pulley mounted on a bracket at right angles to the jib, and carried a small deflecting weight, i.e. a horizontal disturbing force. The scale pan attached to the hoist rope was loaded in increments of $^1/_{10}$ lb and the deflection of the jib head Δ was measured. For points nearing the critical load the reciprocal of the deflection $1/\Delta$ was plotted against the load W on the scale pan. This is a measure of the effective stiffness of the jib and was expected to give a straight line plot for this kind of disturbance.[4] The resulting straight line was extended to the position $1/\Delta=0$ corresponding to the critical load, which could thus be determined without actually breaking the model. The thrust in the model jib P_{crit} was obtained from W_{crit} by drawing a force diagram, making an allowance for friction at the jib head pulleys which was determined by test. A value of the Euler load P_E was obtained for a 10in length of the same strip in the test rig shown in Fig. 6, and found to accord closely with the calculated result at 3·02 lb. Then the equivalent length l is given by definition as

$$L\sqrt{\frac{P_E}{P_{crit}}}.$$

It will be seen from Figs. 4 and 7 that the test results, while following a pattern generally in accordance with the theoretical analysis, show the model jib to be somewhat stronger. This may be accounted for by the use of a model with a very high slenderness ratio (about 1500) for while this was convenient for carrying out the tests, since small weights could be used, it resulted in deflections very much larger in proportion to the length of the jib than would be met in practice. This introduced effects such as a twisting of the jib, increased friction at the hoist rope pulleys, and a tendency for the jib to lift as it deflected, all of which tended to reduce the thrust, and led to over-estimation of the thrust in the force diagram.

Of more interest is the marked difference between experimental and theoretical results when the fixed pulleys are vertically over the jib pivot ($C/A=1$) and the angle of the jib is steep. In such circumstances the derricking rope tends to be very short, and it is considered that with a long jib raised to a very steep angle (as might be found in a guyed derrick crane), it would be possible, as the critical load is approached, for the jib head deflections to be of the same order as the length of the derricking rope between jib head and fixed pulley. In such circumstances a point may be reached at which the jib head cannot deflect further without actually stretching the rope. This greatly increases the restoring forces. Subsequent increases in the load will then cause the jib to deflect in a different way, as shown in Fig. 8, where the double curvature indicates an effective length of less than unity, consistent with anchoring at the top for which the effective length can be as low as $0·7L$ in the limit.

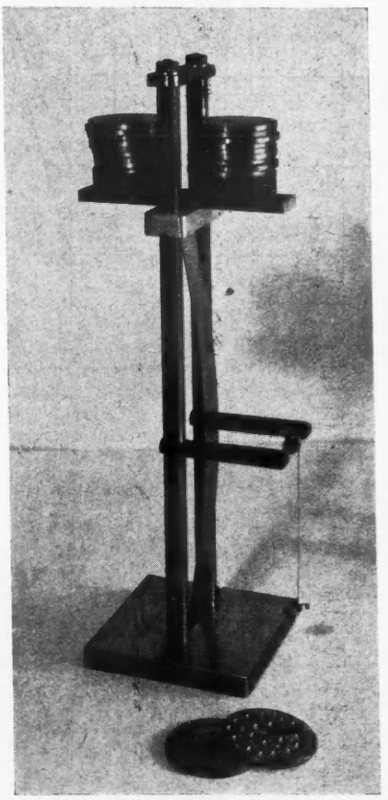


Fig. 6—Determination of Euler load

In practice, however, the increase in strength due to this effect is unlikely to be of consequence in design because small depar-

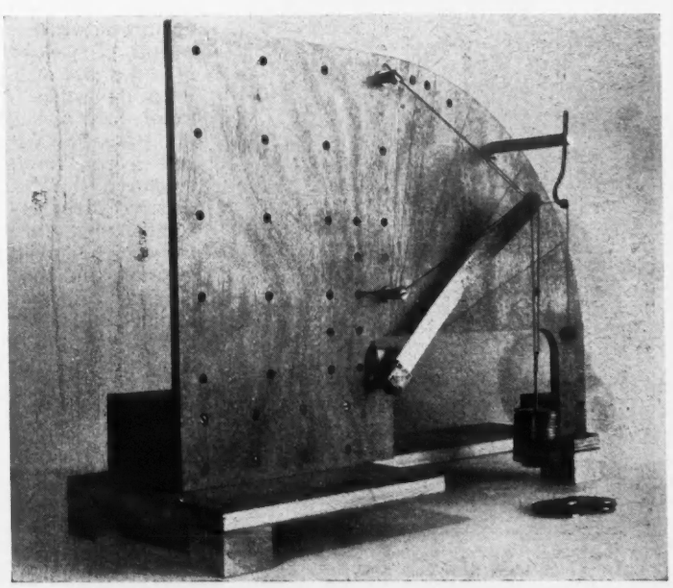
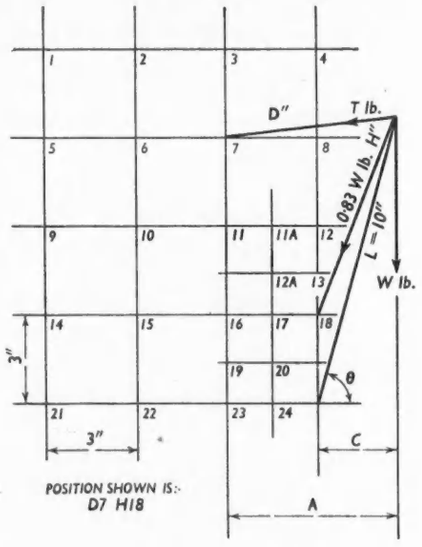


Fig. 5—Test apparatus. The model jib consists of a flexible strip of high-tensile steel, fitted with small pulleys



Dimensions of strut :
Length, 10in ; width, 1in ; thickness, 0·023in.
HT steel.

Euler load, $P_E=\frac{\pi^2 EI}{L^2}=3{\cdot}00$ lb.

Measured value $=3{\cdot}02$ lb.

Friction at pulley represents a loss of 0·17W in the hoist rope.

Equivalent length ratio :

$$E_R=\sqrt{\frac{P_E}{P_{crit}}}.$$

When A has two values A_D and A_H :

$$A=\frac{A_H D+KA_D H}{D+KH}$$

Position			0 deg.	C''	A''	C/A	$K=\frac{T}{0{\cdot}83W}$	P_{crit} lb	Effective length ratio l/L		
									From test	From n^*	From $2-C/A$
D8H18	... ...		5	9·95	9·95	1·0	1·12	3·98	0·88	1·0	1·0
D18H18	... ...		5	9·95	9·95	1·0	2·40	3·33	0·96	1·0	1·0
D8H8	... ...		5	9·95	9·95	1·0	0·42	3·38	0·95	1·0	1·0
D12H12	... ...		45	7·02	7·02	1·0	0·20	3·73	0·90	1·0	1·0
D13H13	... ...		45	7·02	7·02	1·0	0·63	3·44	0·93	1·0	1·0
D18H18	... ...		45	7·02	7·02	1·0	1·71	4·00	0·86	1·0	1·0
D4H12	... ...		45	7·02	7·02	1·0	0·22	4·14	0·86	1·0	1·0
D8H12	... ...		45	7·02	7·02	1·0	0·25	3·85	0·89	1·0	1·0
D8H18	... ...		45	7·02	7·02	1·0	0·58	3·93	0·88	1·0	1·0
D18H18	... ...		65	4·19	4·19	1·0	1·60	3·68	0·90	1·0	1·0
D13H13	... ...		65	4·19	4·19	1·0	0·41	3·47	0·93	1·0	1·0
D13H18	... ...		65	4·19	4·19	1·0	1·01	3·96	0·87	1·0	1·0
D12H18	... ...		75	2·55	2·55	1·0	0·53	4·42	0·83	1·0	1·0
D4H18	... ...		75	2·55	2·55	1·0	0·20	5·26	0·76	1·0	1·0
D8H13	... ...		80	1·76	1·76	1·0	0·07	5·55	0·74	1·0	1·0
D12H13	... ...		80	1·76	1·76	1·0	0·23	3·98	0·88	1·0	1·0
D13H13	... ...		80	1·76	1·76	1·0	0·28	3·41	0·94	1·0	1·0
D4H18	... ...		45	7·02	7·02	1·0	0·49	4·16	0·85	1·0	1·0
D17H17	... ...		5	9·95	11·45	0·87	2·75	2·59	1·08	1·14	1·13
D12AH12A	... ...		5	9·95	11·45	0·87	1·59	2·73	1·05	1·14	1·13
D20H20	... ...		45	7·02	8·52	0·82	2·36	2·32	1·14	1·19	1·18
D24H24	... ...		45	7·02	8·52	0·82	0·135	2·95	1·01	1·19	1·18
D17H17	... ...		45	7·02	8·52	0·82	1·09	2·46	1·11	1·19	1·18
D11AH11A	... ...		45	7·02	8·52	0·82	0·15	2·52	1·10	1·19	1·18
D11AH24A	... ...		45	7·02	8·52	0·82	1·05	2·90	1·02	1·19	1·18
D12AH12A	... ...		65	4·19	5·69	0·74	0·12	2·11	1·20	1·30	1·26
D17H17	... ...		65	4·19	5·69	0·74	0·35	2·19	1·17	1·30	1·26
D24H24	... ...		65	4·19	5·69	0·74	2·39	2·14	1·19	1·30	1·26
D17H24	... ...		65	4·19	5·69	0·74	1·02	2·08	1·20	1·30	1·26
D11H11	... ...		5	9·95	12·95	0·71	1·21	2·30	1·15	1·25	1·23
D16H16	... ...		5	9·95	12·95	0·71	3·05	2·32	1·14	1·25	1·23
D7H16	... ...		5	9·95	12·95	0·71	1·24	2·42	1·12	1·25	1·23
D7H7	... ...		5	9·95	12·95	0·71	0·65	2·26	1·15	1·25	1·23
D11AH17	... ...		75	2·55	4·05	0·63	0·04	1·83	1·28	1·42	1·37
D17H24	... ...		75	2·55	4·05	0·63	0·30	1·74	1·31	1·42	1·37
D17H24	... ...		80	1·76	3·26	0·54	0·18	1·73	1·32	1·51	1·46
D20H24	... ...		80	1·76	3·26	0·54	0·21	1·57	1·39	1·51	1·46
D17H20	... ...		80	1·76	3·26	0·54	0	1·53	1·40	1·51	1·46
D24H24	... ...		80	1·76	3·26	0·54	0·14	1·46	1·44	1·51	1·46
D20H20	... ...		80	1·76	3·26	0·54	0	1·44	1·45	1·51	1·46
D15H15	... ...		45	7·0	13·0	0·54	0·62	1·37	1·48	1·51	1·46
D6H6	... ...		45	7·0	13·0	0·54	0	1·34	1·50	1·51	1·46
D6H15	... ...		45	7·0	13·0	0·54	0·40	1·37	1·48	1·51	1·46
A_D	A_H										
7·76	1·76	D10H13	... ...	80	1·76	1·88	0·94	0·06	2·07	1·20	1·06	1·06
5·6	2·6	D7H13	... ...	75	2·6	2·9	0·9	0·13	2·9	1·0	1·1	1·1
9·95	12·95	D8H16	... ...	5	9·95	11·2	0·89	1·38	2·7	1·06	1·12	1·11
12·95	9·95	D7H18	... ...	5	9·95	11·5	0·86	1·52	2·87	1·02	1·15	1·13
10·02	7·02	D11H18	... ...	45	7·02	8·27	0·85	0·79	2·48	1·10	1·16	1·15
7·02	10·02	D12H23	... ...	45	7·02	8·4	0·83	1·15	2·81	1·04	1·18	1·16
10·02	7·02	D16H18	... ...	45	7·02	8·6	0·82	1·55	2·45	1·11	1·20	1·18
8·6	4·1	D6H20	... ...	75	2·6	4·6	0·57	0·19	1·6	1·4	1·5	1·4
8·6	4·1	D6H24	... ...	75	2·6	4·9	0·53	0·19	1·5	1·4	1·5	1·5
7·7	3·2	D6H20	... ...	80	1·7	3·3	0·52	0·02	1·4	1·4	1·5	1·5
8·6	4·1	D15H24	... ...	75	2·6	5·1	0·51	0·30	1·4	1·4	1·5	1·5
7·7	3·2	D6H24	... ...	80	1·7	3·6	0·47	0·07	1·5	1·4	1·6	1·5
7·7	3·2	D15H24	... ...	80	1·7	3·7	0·45	0·10	1·4	1·5	1·6	1·5

* See text equation (13).

Fig. 7—Results of buckling tests on model jib

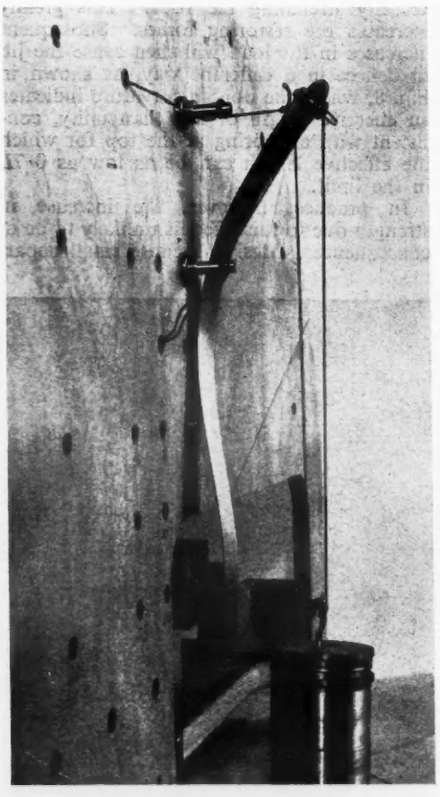


Fig. 8—Double curvature on model jib with a very short derricking rope

tures from the extreme elevation of the jib would normally be sufficient to increase the effective length to unity. The authors consider that the model exaggerated this limiting stiffening effect.

Computation of Compressive Stresses in a Strut

Once the effective length of a strut is known, its effective slenderness ratio can be determined and design can proceed. B.S. 2573 gives in Table II the limiting stresses for axially loaded struts tabulated against slenderness ratios, which are based on the Perry-Robertson formula.

In the case of a crane jib, however, there is the immediate difficulty that it is never axially loaded, but carries bending moments due to its own weight, wind, slewing torque and inertia forces. The method usually employed is to calculate the actual compressive stress as the sum f_a+f_{bc} and to compare this with a permissible limit between the low permissible stress for axial compression, and the higher value allowed for bending compression in Table I of the Standard. This choice is made empirically, by reference to clause 13 in B.S. 2573, using the formula

$$\frac{f_a}{F_a}+\frac{f_{bc}}{F_{bc}}$$

does not exceed unity, or the combined stress f_2 does not exceed

$$f_a+F_{bc}\left(1-\frac{f_a}{F_a}\right). \quad . \quad . \quad . \quad (15)$$

The authors are not able to trace the origin of this widely used expression, which can be employed straightforwardly when axial loads and bending moments are applied to a strut which comprises a single member. When, however, a latticed or battened strut is concerned, the Standard is ambiguous because it is not made clear whether clause 13 should be applied when designing the compression members. Some designers do this, others, reflecting that even though the latticed strut as a whole is bent the loading on the compression members is sensibly axial, will not allow the combined axial and bending stresses to exceed the maximum permissible axial stress corresponding to the slenderness ratio of the strut as a whole.

Whichever method is used, a second step is necessary to ensure that the size of individual compression members between panel points is sufficient to carry the combined stress, which both methods of calculation consider to be axial in this context.

A further ambiguity in the Standard concerns the limiting value of the pure bending stress which may be used in the case of a latticed strut. In B.S. 2573, Table I, the maximum basic stress in the compression flange of a beam is allowed to exceed the maximum for axial compression by 10 to 12 per cent, presumably because extreme fibre stresses are likely to be lowered by plastic deformation. Is this allowance applicable to the compression member of a latticed strut ? In view of these ambiguities, which arise mainly from the empirical nature of methods now used for taking account of bending moments in struts, the authors suggest that it is time to reconsider these methods, and formulate alternative methods

of designing struts for cranes which take proper account of applied bending moments and which can be used with justification for latticed struts.

Such a method might develop from a reconsideration of the origins of the Perry formula[6] which derives from the expression :

$$f=\frac{P\varepsilon}{Z\left(1-\frac{P}{P_E}\right)}+f_a \quad . \quad . \quad . \quad (16)$$

which is a statement that the bending stress induced by " out of straightness " in a pin-ended strut is magnified by reason of an axial load P by a factor

$$\frac{1}{1-\frac{P}{P_E}}.$$

So as to embrace other end conditions in the strut and to account for the effective length, this factor might be written

$$\frac{1}{1-\frac{P}{P_{crit}}}.$$

Now $P\varepsilon/Z$ can be written

$f_a\frac{\varepsilon a}{r^2}$, or ηf_a if $\eta=\frac{\varepsilon a}{r^2}$. Also $\frac{P}{P_{crit}}=\frac{f_a\left(\frac{l}{r}\right)^2}{\pi^2E}$

which allows us to make use of our effective length determination for the jib of a crane.

Hence writing P_{crit} for P_E the expression (16) becomes

$$f=f_a+\frac{\eta f_a}{\left[1-\frac{f_a}{\pi^2E}\left(\frac{l}{r}\right)^2\right]}.$$

Now in load factor design (as used in B.S. 2573 for struts) the structure is designed to withstand a stress of K_2 times the working stress, where K_2 is the assigned load factor. Hence the bending stress under factored load becomes

$$f=K_2f_a+\frac{\eta K_2f_a}{\left[1-\frac{K_2f_a}{\pi^2E}\left(\frac{l}{r}\right)^2\right]}$$

or we may say

$$f_2=\frac{f}{K_2}=f_a+\frac{\eta f_a}{\left[1-\frac{K_2f_a}{\pi^2E}\left(\frac{l}{r}\right)^2\right]} \quad . \quad . \quad (17)$$

Now in the limiting case, with impending collapse, f becomes the yield stress F_y and f_a becomes the maximum permissible axial stress F_a with no other disturbance than out-of-straightness, and

$$\frac{F_y}{K_2}=F_a+\frac{\eta F_a}{\left[1-\frac{K_2F_a}{\pi^2E}\left(\frac{l}{r}\right)^2\right]} \quad . \quad . \quad . \quad (18)$$

And if this expression is solved for F_a, the well-known Perry formula is obtained :

$$F_a=\frac{1}{K_2}\left[\frac{F_y+(\eta+1)F_e}{2}-\sqrt{\left(\frac{F_y+(\eta+1)F_e}{2}\right)^2-F_yF_e}\right]$$

In the form shown in (17), however, f_a may be any working axial stress and f_2 is the extreme fibre stress resulting from the axial load. This therefore presents an alternative method for designing struts : if the axial working stress is magnified by a factor

$$1+\frac{\eta}{\left[1-\frac{K_2f_a}{\pi^2E}\left(\frac{l}{r}\right)^2\right]};$$

Table II in B.S. 2573 is not required and the resulting extreme fibre stress can be allowed, whatever the value of the slenderness ratio, to reach a maximum of F_y/K_2 (or, in B.S. 2573, 9·0 tons per square inch for B.S. 15 steel), and when this happens, the result will be exactly equivalent to that obtained when the method specified in B.S. 2573 is used and $f_a=F_a$.

We may now consider the addition of bending moments, which the authors suggest may be looked upon as increasing the " out-of-straightness " allowed for in the expression (17). In other words it is suggested that any bending stress f_{bc} induced by external loads would be magnified, if the strut has an axial stress f_a, by the factor

$$\left[\frac{1}{1-\frac{P}{P_{crit}}}\right]$$

in the same way as for the bending stress $P\varepsilon/Z$ resulting from the original " out-of-straightness." This statement is conservative, being sensibly true when the external loads which cause bending themselves induce the configuration associated with failure of the strut at the critical load, but for all other external loads likely to be encountered in a crane the magnification factor is too large ; however, the authors suggest that this bending stress magnification factor should be applied in all cases for the sake of simplicity. It takes care of the worst case, and it is only about the weak axis that the conservatism is noticeable.

An expression for the combined stress due to bending and axial compression would then be :

$$f_2=f_a+\frac{\eta f_a}{\left[1-\frac{K_2f_a}{\pi^2E}\left(\frac{l}{r}\right)^2\right]}+\frac{f_{bc}}{\left[1-\frac{K_2f_a}{\pi^2E}\left(\frac{l}{r}\right)^2\right]}$$

or for steel

$$f_2=f_a+\frac{\eta f_a}{\left[1-\frac{K_2f_a}{13}\left(\frac{l}{100r}\right)^2\right]}+\frac{f_{bc}}{\left[1-\frac{K_2f_a}{13}\left(\frac{l}{100r}\right)^2\right]} \quad . \quad . \quad . \quad . \quad . \quad (19)$$

This expression has greater reality than the equivalent $f_2=f_a+f_{bc}$ given in clause 13 of B.S. 2573, and need admit of no ambiguity as regards the maximum permissible value of f_2 which is, in all cases of single-member struts, F_y/K_2. The incorporation of a second bending moment, in a plane at right angles to the first would involve a further term with a different magnification factor arising from the different value of the slenderness ratio in that plane. Thus the whole expression for the combination of axial stress with two moments at right angles would be :

$$f_2\left(\text{not to exceed }\frac{F_y}{K_2}\right)=f_a+\frac{\eta f_a+f_{bc}}{1-\frac{K_2f_a}{13}\left(\frac{l}{100r}\right)^2}+\frac{f_{bc}^1}{1-\frac{K_2f_a}{13}\left(\frac{l^1}{100r^1}\right)^2} \quad . \quad . \quad . \quad (20)$$

This expression is somewhat lengthy, and it is necessary to simplify the calculations for designers. However, putting the expression in the form

$$f_2\left(\text{not to exceed }\frac{F_y}{K_2}\right)=f_a+\omega_1(\eta f_a+f_{bc})+\omega_2f_{bc}^1 \quad . \quad . \quad . \quad . \quad . \quad (21)$$

values of ω_1 and ω_2 can readily be obtained from a chart as shown in Fig. 9.

TABLE I—*Comparison of Three Methods of Calculation*

Method	Computed stress in compression f_2	Basic permissible stress in members F_2
(1) B.S. 2573 without clause 13	$f_a+f_{bc}+f_{bc}^1$	F_a
(2) B.S. 2573 with clause 13	$f_a+f_{bc}+f_{bc}^1$	$f_a+F_{bc}\left(1-\frac{f_a}{F_a}\right)$
(3) Proposed ...	$f_a+\omega_1(\eta f_a+f_{bc})+\omega_2f_{bc}^1$	F_y/K_2

At this stage it is worth while to compare the three methods of calculating the section area of a strut which have been described as in Table I above.

A comparison may be made by reference to Fig. 10, which deals with basic stresses for B.S. 15 steel, and for the sake of simplicity, assumes that the struts considered have bending moments applied in only one plane ($f_{bc}^1=0$). If method (1) is used, the sum of the axial and bending stresses in the compression member must not be allowed to exceed the limiting axial stress corresponding to the slenderness ratio of the strut as a whole. This value is given on the chart, Fig. 10, for each of three slenderness ratios, 140, 70, and 0 as the points where the sloping lines cut the base line. If the slenderness ratio of the strut is high, both axial and bending stresses are limited to very low values. The application of clause 13 in such a case (method (2)) gives considerable relief, the ordinates of points on the dotted line giving the limiting values of axial and bending stresses. Thus for $l/r=140$ with an axial stress of 1½ tons per square inch a bending stress as high as 5 tons per square inch would be permissible by method (2), whereas by method (1), without the application of clause 13, the bending stress could not exceed 1½ tons per square inch. Comparable limiting (unmagnified) stresses applicable to the proposed method (3) are given by the ordinates of points on the curved full lines in the chart, Fig. 10, and it will be seen that the allowable stresses are rather lower than would be permissible by method (2). The difference, however, is largely due to the difference in the value of the limiting stress in a case of pure bending, which is considered to be permissible by both methods, and if these were the same, there would be little difference between the two methods. It seems reasonable to assume that providing the strut is a single member so that extreme fibre stresses are likely to be relieved by plastic deformation, a limiting basic bending stress slightly higher than F_y/K_2 might be allowed, as is permitted in B.S. 2573.

This investigation, therefore, may be said to have justified the use of clause 13 in B.S. 2573 in the case of struts comprising a single member. This justification cannot, however, be extended to latticed or battened struts without further consideration.

Case of a Latticed or Battened Strut

Although the magnification factor

$$\frac{1}{1-\frac{P}{P_{crit}}}$$

applies strictly to the extreme fibre stress in a strut which comprises a single member, recent investigations into the stability of framed structures[2, 4, 5] justify its extension to the approximate magnification of bending stresses in a latticed or battened strut. In such a case the stress f_2 (see equation (20)) becomes the compression stress in an outer member of the lattice and can be considered to be axial. This outer member is also a strut between the intersection of bracings and must be proportioned so as to resist local buckling. Thus, the stress f_3, determined from equation (20) will be further magnified by reason of out-of-straightness in the member between panel points,† and the extreme fibre stress in the member will be

$$f_3=f_2+\frac{\eta_1f_2}{1-\frac{K_2f_2}{13}\left(\frac{l_m}{100r_m}\right)^2} \text{ or } f_3=f_2+\omega_3\eta_1f_2 \quad . \quad . \quad . \quad . \quad . \quad (22)$$

where l_m/r_m is the slenderness ratio of the compression member between panel points.

† Strictly speaking, the concept of "local buckling" is somewhat artificial, since the collapse of the individual member depends not only on its own form, but on the shape of the latticed strut as a whole.

The limiting value of this stress would normally be F_y/K_2, but as it is a single member strut, and the extreme fibre stress would be relieved by plastic deformation, the slightly higher basic stress allowed in Table I, B.S. 2573, for the compression flanges of beams might be allowed in this part of the calculation, though not earlier when the latticed strut is considered as a whole.

It will be seen, therefore, that both the existing methods of calculation underestimate the real stress in the compression member of a latticed strut. If B.S. 2573 is followed without invoking clause 13 (method (1), Table I), this error is over-compensated for by the specification of an artificially low limiting stress F_a. If clause 13 is applied (method (2)), the error is under-compensated. While the slenderness ratio of the latticed strut as a whole is low, there is little practical difference in the results of these three methods, but at higher overall slenderness ratios, following B.S. 2573 without invoking clause 13, will result in an unnecessarily conservative design, while invoking clause 13 (with a value of $F_{bc}=F_y/K_2$) leads to results which are slightly optimistic, particularly in regard to the spacing of bracing members.

If this empirical method is used, it is important that the value of F_{bc} which is used does not exceed F_y/K_2 because higher values give over-optimistic results. An example showing the three methods of calculation as applied to a crane jib is given in the Appendix.

Value of η

The value of η given in B.S. 2573 and used in the above comparison is $0{\cdot}003\frac{l}{r}$ and this value is attributable to Robertson. However, the Steel Structures Research Committee[7] advocated a lower value of $0{\cdot}0015\frac{l}{r}$ as long ago as 1936, basing their recommendation on measurements of the straightness of struts made from " I " section joists. It is perhaps time that further measurements should be made, of latticed struts as well as single member struts, of the types to be found in crane design, particularly in jibs, with a view to confirming or modifying the present value. It would cause no great difficulty if different values of η were specified for single members and latticed struts, and it is possible that the value could be generally lowered. Thus, in the case of latticed struts, if

$\eta=\frac{\varepsilon_a}{r^2}=0{\cdot}003\frac{l}{r}$, then $\varepsilon=0{\cdot}003\frac{l}{r}\cdot\frac{r^2}{a}$ and as $\frac{r}{a}$ can be taken as unity in a latticed strut, a value of $\eta=0{\cdot}003\frac{l}{r}$ implies an initial " out-of-straightness " of the order of three thousandths of the length, that is $3\frac{1}{2}$in in a jib 100ft long—an error that might perhaps be considered abnormal, and the present design rules correspondingly over-conservative.

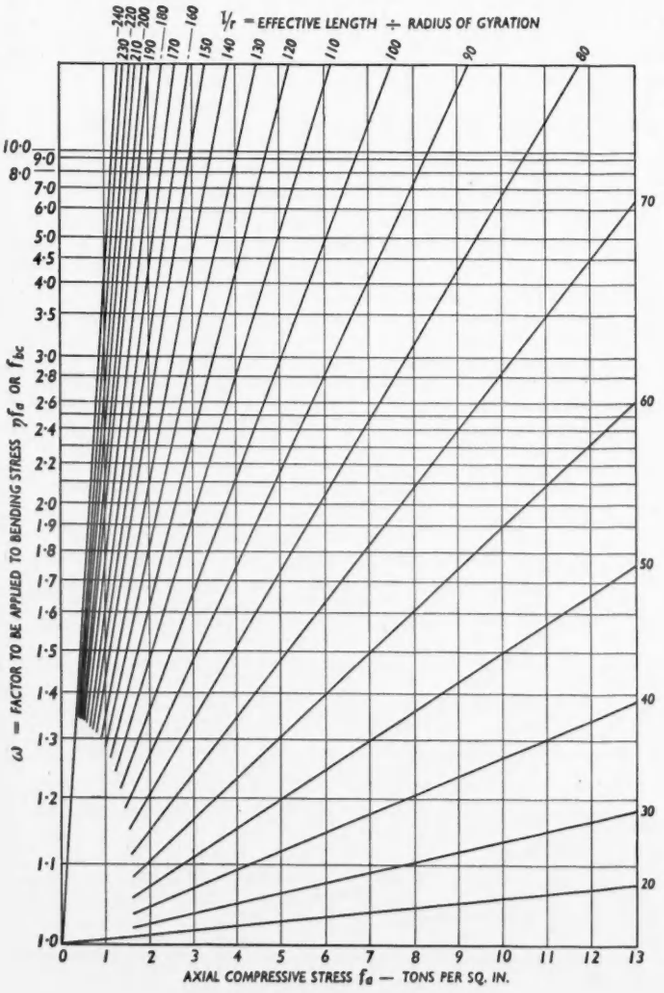
Conclusions

(1) An investigation has shown that the stiffness of the jib of a luffing crane in a plane normal to that of luffing depends upon the angle to which the jib is luffed and the positions of the fixed pulleys over which pass the luffing rope and the hoist rope. The effective length of the jib in the plane normal to luffing may be calculated from a simple formula due to Mr. S. Hall, namely $l/L=2-C/A$ where l/L is the ratio of the effective length to the real length of the jib, and C and A are simple dimensions described in the text.

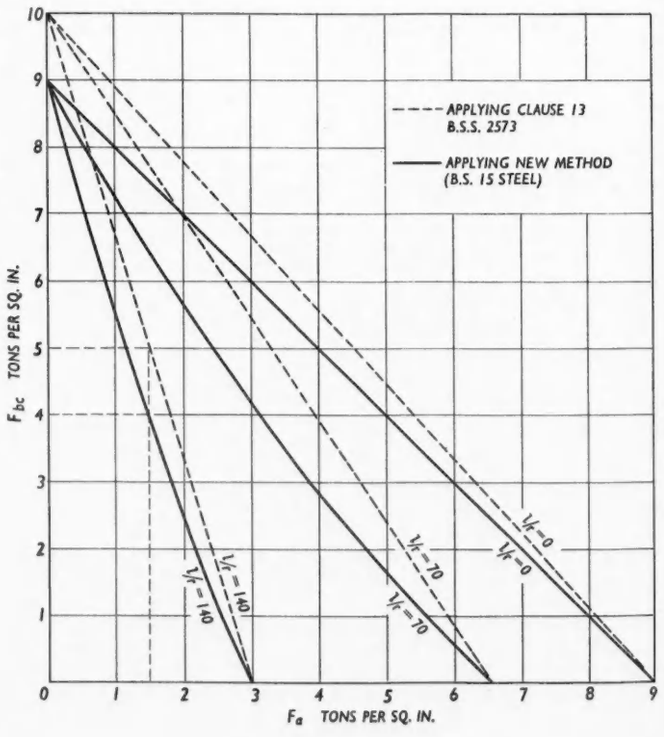
(2) A theoretical investigation into the validity of the use of the empirical formula given in clause 13, B.S. 2573, shows that this may be used with justification in the case of struts comprising a single member. The value of F_{bc} to be used in this context should be derived from the basic stress given in Table I B.S. 2573, for the compression flange of beams other than plate girders.

(3) The design of latticed or battened struts, following B.S. 2573 without invoking clause 13, leads to unnecessary conservatism in the case of slender struts ; on the other hand, if clause 13 is applied, the design is somewhat optimistic, and the limiting value of F_{bc} should not exceed $F_y/K_2\times$(stress factor), or could well be slightly lower.

(4) In investigating the validity of existing empirical methods for the design of struts carrying bending moments, the authors have proposed a method which they suggest might well replace existing calculations as these under-estimate the stresses involved. The proposed method can be applied with justification to the design of the compression members of a latticed or battened strut and enables an approximation to the real stress in these members to be calculated quickly with the aid of a chart. It is thus safer to use in special cases where additional stresses such as torsion are involved, or when high-tensile steel is used, leading to higher slenderness ratios. A further advantage of the proposed method is that without drastic revision it can incorporate future refinements in design procedure involving such considerations as a different load factor, or a value of the out-of-straightness η which varies according to the construction used.


l/r = EFFECTIVE LENGTH ÷ RADIUS OF GYRATION
ω = FACTOR TO BE APPLIED TO BENDING STRESS pfa OR fbc
AXIAL COMPRESSIVE STRESS fa — TONS PER SQ. IN.

(Left) Fig. 9—Bending stress magnification factors for steel struts with load factor = 1·7



(Above) Fig. 10—Maximum permissible values of basic stresses F_a and F_{bc} for various slenderness ratios

(5) The authors suggest that measurements should be undertaken to confirm the present-day validity of the value $\left(0{\cdot}003\frac{l}{r}\right)$ of η used in the Perry-Robertson formula.

APPENDIX

Examples of Calculation

A crane jib is to be designed to the following specification (see Fig. 11) :

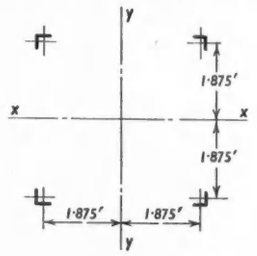


Fig. 11

Class 1 crane.
Structural steel to B.S. 15.
Length of jib=154ft.
$2-C/A=1{\cdot}1$.
$r=1{\cdot}875$ft.
$l/r=82$ in plane of luffing.
$l^1/r=90$ about other axis.
Axial thrust=30 tons.
Maximum B.M. in luffing ptane=50ft tons.
Maximum B.M. in slewing plane=25ft tons.

Example (a) Designed to B.S. 2573 Ignoring Clause 13.—

Corner angles 4in by 4in by $\frac{1}{2}$in. Area=3·75 square inches. Maximum r_m=0·78in.

Considering jib as a whole :

Maximum l/r=90. Basic compressive stress =5·44 tons per square inch.

Therefore,

Permissible compressive stress=$5{\cdot}44\times0{\cdot}85$.

i.e. $F_2=5{\cdot}44\times0{\cdot}85=4{\cdot}63$ tons per square inch.

$$f_a=\frac{30}{4\times3{\cdot}75}=2{\cdot}00 \text{ tons per square inch.}$$

$$f_{bc}=\frac{50}{2\times3{\cdot}75\times3{\cdot}75}=1{\cdot}78 \text{ tons per square inch.}$$

$$f_{bc}{}^1=\frac{25}{2\times3{\cdot}75\times3{\cdot}75}=0{\cdot}89 \text{ ton per square inch.}$$

Therefore,

$f_2=2{\cdot}00+1{\cdot}78+0{\cdot}89=4{\cdot}67$ tons per square inch (acceptable).

Considering individual panel length :

$\frac{4{\cdot}67}{0{\cdot}85}=5{\cdot}5$ tons per square inch which allows $\frac{l_m}{r_m}=88$.

Therefore,

$$\frac{0{\cdot}85L}{0{\cdot}78}=88. \qquad L=\frac{88\times0{\cdot}78}{0{\cdot}85}=81\text{in.}$$

Therefore, panel length not greater than 6ft 9in.

Example (b) Designed to B.S. 2573, Applying Clause 13.—Corner angles $3\frac{1}{2}$in$\times3\frac{1}{2}$in$\times\frac{7}{16}$in.

Area=2·87 square inches. Minimum r_m =0·68in.

Considering jib as a whole :

l/r=90, therefore, basic axial compressive stress =5·44 tons per square inch and permissible axial compressive stress, $F_a=5{\cdot}44\times0{\cdot}85=4{\cdot}63$ tons per square inch. Permissible stress in bending compression, $F_{bc}=9\times0{\cdot}85=7{\cdot}65$ tons per square inch.

$$f_a=\frac{30}{4\times2{\cdot}87}=2{\cdot}6 \text{ tons per square inch.}$$

$$f_{bc}=\frac{50}{2\times2{\cdot}87\times3{\cdot}75}=2{\cdot}3 \text{ tons per square inch}$$

$$f_{bc}{}^1=\frac{25}{2\times2{\cdot}87\times3{\cdot}75}=1{\cdot}15 \text{ tons per square inch.}$$

Therefore,

$f_2=2{\cdot}6+2{\cdot}3+1{\cdot}15=6{\cdot}05$ tons per square inch.

Applying clause 13 :

$$F_2=2{\cdot}6+7{\cdot}65\left(1-\frac{2{\cdot}6}{4{\cdot}63}\right)=2{\cdot}6+3{\cdot}37$$

$=5{\cdot}97$ tons per square inch,

hence, f_2 might be considered acceptable.

Considering individual panel lengths :

$\frac{6{\cdot}05}{0{\cdot}85}=7{\cdot}12$ tons per square inch which allows $\frac{l_m}{r_m}=58$.

Therefore,

$$\frac{0{\cdot}85L}{0{\cdot}68}=58. \qquad L=\frac{58\times0{\cdot}68}{0{\cdot}85}=46{\cdot}4\text{in.}$$

Therefore, panel length not greater than 3ft 10in.

Example (c) Designed by Proposed Method.—Corner angles $3\frac{1}{2}$in$\times3\frac{1}{2}$in$\times\frac{1}{2}$in.

Area=3·25 square inches. Minimum r_m =0·68in.

Considering jib as a whole :

$$f_a=\frac{30}{4\times3{\cdot}25}=2{\cdot}3 \text{ tons per square inch.}$$

$$f_{bc}=\frac{50}{2\times3{\cdot}25\times2{\cdot}75}=2{\cdot}05 \text{ tons per square inch.}$$

$$f_{bc}{}^1=\frac{25}{2\times3{\cdot}25\times3{\cdot}75}=1{\cdot}03 \text{ tons per square inch.}$$

$l/r=82$. Therefore, $\eta=0{\cdot}003\times82=0{\cdot}246$, and (using Fig. 6) $\omega_1=1{\cdot}26$.

$l^1/r=90$ and (using Fig. 6) $\omega_2=1{\cdot}32$.

$f_2=2{\cdot}3+1{\cdot}26\,(0{\cdot}246\times2{\cdot}3+2{\cdot}05)$ $+1{\cdot}32\times1{\cdot}03$ (equation (21))

$=2{\cdot}3+3{\cdot}3+1{\cdot}36$

$=6{\cdot}96$ tons per square inch, which is acceptable since allowable $F_2=\frac{15{\cdot}25\times0{\cdot}85}{1{\cdot}7}$ $=7{\cdot}65$ tons per square inch.

Considering individual panel length :

As in equation (22) :

$f_3=f_2+\omega_3\eta f_2$ and must not exceed $10\times0{\cdot}85$ tons per square inch.

To find acceptable slenderness :

$8{\cdot}5=6{\cdot}96+\omega_3\times0{\cdot}003\frac{l_m}{r_m}\times6{\cdot}96$. This equation is satisfied when $\frac{l_m}{r_m}=54$, and $\omega_3=1{\cdot}37$ (values obtained by trial and error from Fig. 6).

Therefore,

$$\frac{0{\cdot}85L}{0{\cdot}68}=54. \qquad L=\frac{54\times0{\cdot}68}{0{\cdot}85}=43\text{in.}$$

Therefore, panel length not greater than 3ft 7in.

The difference between the results of the three methods for this jib is shown in the table below :

B.S. 2573 without clause 13	B.S. 2573 with clause 13	Proposed method
4in×4in×$\frac{1}{2}$in corner angles Panel length not to exceed 6ft 9in	3$\frac{1}{2}$in×3$\frac{1}{2}$in×$\frac{7}{16}$in corner angles Panel length not to exceed 3ft 10in	3$\frac{1}{2}$in×3$\frac{1}{2}$in×$\frac{1}{2}$in corner angles Panel length not to exceed 3ft 7in

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Sensitivity of Slow Shifting Under Stick-Slip Conditions

By B. R. SINGH, B.Sc. (Eng.) Hons., M.Tech., A.M.I.E. (India)*

The motion of flexible systems at slow velocities under boundary friction, may, under certain circumstances, proceed in a discontinuous or stick-slip form. Such motion is detrimental to the accuracy and sensitivity in precision appliances, machine tools and automatic controls where very high accuracies are required. This paper presents a theoretical analysis and experimental investigation of the error and the sensitivity of such adjustments. The results obtained are represented graphically in non-dimensional form. The effect of the various physical and dynamical parameters of the flexible system, such as damping, stiffness, difference of static and kinetic friction forces, the ratio of average velocity of sliding to its critical value, &c., is then discussed from the point of view of improving the sensitivity of such controls.

WITH the expanding field of the aircraft, atomic energy, armament and other industries there is an increasing demand for high precision machine tools where the jigs and some other of the components can be produced directly. In such machine tools precision automatic control is often required continuously, of which very high accuracies are demanded. The most common example of such high precision machine tools is the jig boring machine. The essential requirement here is that an accuracy of, say, 0·0001in is obtained in each and every setting obtained by automatic positioning.

It is apparent that conventional sideways and driving mechanisms would not permit of machine tool tables repeating their positions to the same limit every time under automatic control so that electronic control devices are often employed rather than mechanical devices such as cams and linkages. During such a process of positioning of a table, although the driving motor (input) may be rotating smoothly, the driven table (output) motion usually breaks down into a series of jumps and proceeds in a stick-slip form, particularly at the low speeds employed in effecting the final adjustment.

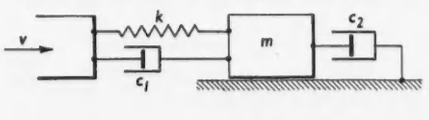

Fig. 1—Elastic Sliding System

In addition to the precision machine tools as mentioned in the foregoing, the problem of such discontinuous motion may also be experienced in other precision instruments, servo-mechanisms, &c.

The Mechanics of Stick-Slip

In general an actual elastic system comprising the driving and driven members may be represented in an idealised form as shown in Fig. 1. Consider a drive of uniform velocity

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v, effective stiffness k, and a driven member of mass m sliding under boundary friction over a surface which is relatively rigid. The damping resistance offered to motion is represented by means of two dampers, where c_1=the coefficient of equivalent viscous damping between the sliding mass and the drive (including internal friction of material, structural friction of joints and external damper, if any); and c_2=the coefficient of equivalent viscous damping between the rubbing surfaces. While the drive moves at a constant velocity, the motion of the mass or the slip begins when the compressive force in the spring just overcomes the static frictional resistance F_0. At the end of the slip or jump, the mass again sticks to the lower surface and the process is then repeated indefinitely.

The equation of motion of the mass m is then given[1, 2] by

$$mx''+(c_1+c_2)x'+kx=F+kvt+c_1v \quad . \quad (1)$$

where ΔF=the difference between the static and kinetic friction forces between the rubbing surfaces. Using the initial conditions at

$$t=0,\ x=0,\ x'=0 \quad . \ . \ . \ . \quad (2)$$

the solution for equation (1) for displacement and velocity of the mass are obtained for the usual range of damping ratios obtained in practice ($\xi_1^2 \ll 1$, $\xi_2^2 \ll 1$) as

$$x=\frac{\Delta F}{k}+vt+\frac{2\xi_1 v}{\omega_n}-\frac{v}{\omega_n}e^{-\xi'\omega_n t}[(A+2\xi_1)\cos\omega_n t + (1+A\xi_1)\sin\omega_n t] \quad . \ . \ . \quad (3)$$

$$x'=\frac{\Delta F}{m}e^{-\xi'\omega_n t}\left[\left(1+\frac{2\xi'}{A}+\frac{2\xi_1}{A}\right)\cos\omega_n t + \left(\frac{1}{A}-\xi'\right)\sin\omega_n t\right] \quad . \ . \ . \quad (4)$$

where

$$\xi_1=\frac{c_1}{2\sqrt{mk}}\ ;\quad \xi_2=\frac{c_2}{2\sqrt{mk}}\ ;\quad \xi'=\xi_1+\xi_2\ ;$$

and A is a dimensionless parameter given by

$$A=\frac{\Delta F}{v\sqrt{km}} \quad . \ . \ . \ . \ . \quad (5)$$

and $\omega_n=\sqrt{k/m}$ natural circular frequency of the elastic system.

It has been shown theoretically and experimentally[3, 4] that on the one hand for the foregoing system, the mass moves in the stick-slip form for all velocities of the drive less than or equal to a critical value v_c, given by

$$v_c=\frac{\Delta F}{\sqrt{km}},\ \frac{1}{A_c} \quad . \ . \ . \ . \quad (6)$$

where A_c is a dimensionless parameter and a function of the damping ratios of the two dampers, and is given by

$$2\xi'\left[\frac{A_c+2\xi'+2\xi_1}{A_c\xi'-1}\right]=\log[A_c^2+2(\xi'+2\xi_1)A_c + 2\xi'^2+6\xi_1\xi'+4\xi_1^2+1] \quad . \ . \quad (7)$$

On the other hand, for all velocities of the drive greater than the critical velocity as given above, the motion of the driven mass takes place in a smooth or continuous form.

Error and Sensitivity of Slow Shifting

In practice the shifting of the mass, during final adjustments particularly in automatic controls, is usually effected at very slow speed (lower than the critical velocity of a particular system) so that motion of the mass would generally occur in the stick-slip form as indicated in the foregoing. Thus it may be mentioned that in the case of servo-mechanisms, a frictional load F_0 is introduced by the equipment on the output shaft and the bearings of the servo-motor. An error F_0/k should therefore be added to the errors produced by other sources, when the output changes direction this error changes from (F_0/k) to $(-F_0/k)$. The input may move back and forth within a distance of $(2F_0/k)$ while the output is stationary, producing a force large enough to drive the output shaft.

Thus referring to Fig. 1, the displacement x_1 of the drive at any time T is given by

$$x_1=\frac{F_0}{k}+vT \quad . \ . \ . \ . \ . \quad (8)$$

where the time T is measured from the instant, the driven member slips and is given by

$$T=n(t_1+t_2)+t \quad . \ . \ . \ . \quad (9)$$

where n=number of complete jumps; t_1=time taken for a jump; t_2=time elapsed during a stick; t=time during the last fractional slip (see Fig. 2). The displacement x_2 of the driven member m at any time T is given from equation (3) by

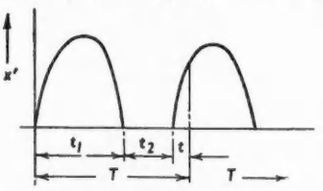

Fig. 2—Instantaneous velocity x' of sliding mass and periods of slip t_1 and stick t_2

$$x_2=n(t_1+t_2)v+\frac{\Delta F}{k}+vt+\frac{2\xi_1 v}{\omega_n} -\frac{v}{\omega_n}e^{-\xi'\omega_n t}[(A+2\xi_1)\cos\omega_n t+(1+A\xi')\sin\omega_n t] \quad . \ . \ . \ . \ . \quad (10)$$

It will be noted here that the time t_1 for complete jump is given by $(dx_2/dt)_t=t_1=0$, i.e. by

$$(x_2')_{t=t_1}=v\left\{1-e^{-\xi'\omega_n t_1}[\cos\omega_n t_1 - (A+\xi'+2\xi_1)\sin\omega_n t_1]\right\} \quad . \quad (11)$$

and the time t_2 of stick is given by

$$F=kvct_2 \quad . \ . \ . \ . \ . \quad (12)$$

The error of shifting e between the drive and the driven mass at any time is then given by $e=x_1-x_2$. At the start of any jump of the mass, i.e. at $t=0$, the error

$$e_1=F_0/k \quad . \ . \ . \ . \ . \quad (13)$$

At the completion of a jump of the mass, i.e. at $t=t_1$, the error of shifting e_2 is given by

$$e_2=\frac{F}{k}-\frac{2\xi_1 v}{\omega_n}+\frac{v}{\omega_n}e^{-\xi'\omega_n t_1}[(2\xi_1+A)\cos\omega_n t_1 + (1+A\xi')\sin\omega_n t_1] \quad . \ . \quad (14)$$

The difference s between the errors before and after the slip may be expressed in the following form

$$\delta=\frac{\Delta F}{k}\left\{1+\frac{2\xi_1 vk}{\omega_n\Delta F}-\frac{vk}{\Delta p\omega_n}e^{-\xi'\omega_n t_1}[(2\xi_1+A)\cos\omega_n t_1 + (1+A\xi')\sin\omega_n t_1]\right\} \quad . \ . \quad (15)$$

Equation (15) may be written in a convenient non-dimensional form thus,

$$\left(\frac{\delta}{\frac{\Delta F}{k}}\right)=1+\frac{v}{v_c A_c}\left\{2\xi_1-e^{-\xi'\omega_n t_1}\left[\left(2\xi_1+\frac{v_c A_c}{v}\right)\cos\omega_n t_1+\left(1+\frac{v_c A_c\xi'}{v}\right)\sin\omega_n t_1\right]\right\} \quad . \ . \ . \ . \ . \quad (16)$$

where $\left(\frac{\delta}{\Delta F/k}\right)$ is a dimensionless parameter,

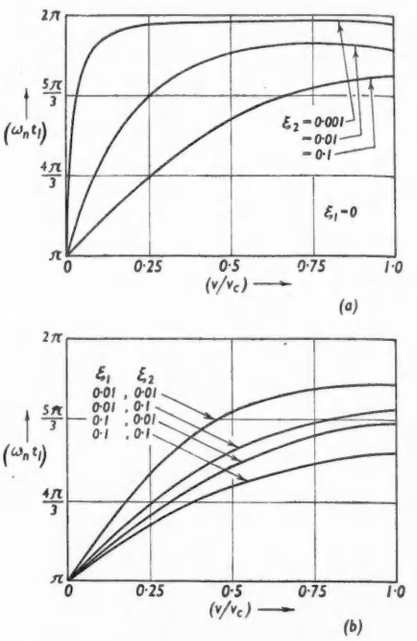

Fig. 3—Curves for period of slip t_1 with different damping ratios ξ_1, ξ_2 and velocities of drive v

the inverse of which is a measure of the sensitivity of a particular system. Thus a smaller value of the parameter characterises a more sensitive system and a smaller value of the parameter a less sensitive system.

To obtain a solution of Equation (16) it may be first noted that Equation (11) can be written as

$$e^{-\xi'\omega_n t_1}\left[\cos\omega_n t_1-\left(\frac{A_c v_c}{v}+\xi'+2\xi_1\right)\sin\omega_n t_1\right]=1 \quad . \ . \ . \ . \ . \quad (17)$$

with its graphical representation as shown in Figs. 3 (*a*) and 3 (*b*) for some typical values of damping ratios. Equation (16) may then be represented graphically as shown in Fig. 4 for some typical values of

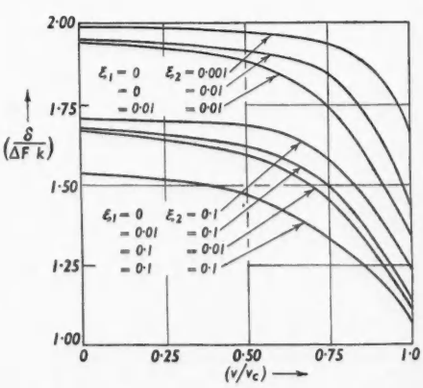

Fig. 4—Curves for sensitivity of shifting for different velocities of drive v and damping ratios (ξ_1, ξ_2)

damping ratios for the range of (v/v_c) between 0 and 1.

It will be of interest to observe that in particular for the case with damping neglected, i.e. $\xi_1=\xi_2=0$, Equations (11) and (14) reduce, respectively to the form

$$1=\cos\omega_n t_1-A\sin\omega_n t_1 \quad . \ . \ . \quad (18)$$

and

$$e_2=\frac{F}{k}+\frac{v}{\omega_n}[A\cos\omega_n t_1+\sin\omega_n t_1] \quad . \quad (19)$$

Eliminating $\omega_n t_1$, from these equations,

$$e_2=-\frac{F_0-2F}{k} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (20)$$

and hence

$$\delta=\frac{F_0}{k}+\frac{F_0-2F}{k}=\frac{2\Delta F}{k} \quad . \quad . \quad . \quad . \quad (21)$$

Experimental Investigations

Fig. 5 shows a photograph of a model, represented schematically by Fig. 1, and arranged on a Cincinnati milling machine.

The mass m comprises a steel block that moves in a corresponding steel slide block clamped to an angle cleat connected to the milling head. The mass is driven by the table through a vertical plate spring and a driving pin. A dashpot filled with oil, clamped to the table, is also introduced. The piston for the dashpot is carried on the driving pin. Two different stiffness constants (k=100 lb per inch and 50 lb per inch) were obtained by changing the spring plates and adjusting the clamping pressure. The rubbing surfaces, ground fine, were lubricated with paraffin oil so that the coefficients of friction were obtained as $\mu_s=0\cdot2$ and $\mu_k=0\cdot15$.

Measurement of damping (log decrement) was done by means of free vibration tests. The frictional resistance between the mass and the slide was practically reduced to negligible values by sliding the mass over steel balls introduced into specially prepared "V"-grooves between the rubbing surfaces. The damping with the dashpot removed, thus measures ξ_2 approximately. Thus a value of $\xi_2=0\cdot01$ was obtained with k= 100 lb per inch. W=5 lb; and k=50 lb per inch, W=10 lb. The ratio ξ' was determined with the dashpot introduced in the system so that ξ_1 is known. Variation in ξ_1 was obtained by varying the depth of piston submerged in thick oil so that two values of $\xi_1=0\cdot01$ and $0\cdot1$ approximately were obtained for k=100 lb per inch. W=5 lb and also for k=50 lb per inch; W=5 lb.

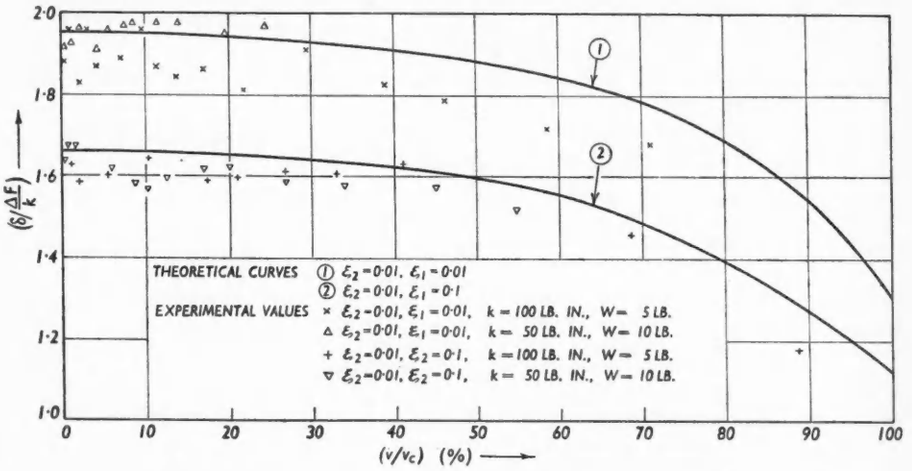

Fig. 6—Theoretical curves and experimental values for sensitivity

Measurement of δ at different velocities of drive (tabulated below) was made by means of a dial indicator (reading up to 0·0001in) attached to the table by a magnetic base and pointing to the driving pin. The zero of the dial was set at F_0/k. A larger number of readings was taken at very low velocities, since in general for most cases of controls in practice, the shifting required for final adjustment of position is effected at very low velocities. The experimental results for $\left(\frac{\delta}{\Delta F/k}\right)$ have been plotted (see Fig. 6) against the ratio of velocity of drive to the critical velocity for different damping ratios in the following cases :

I—W=5 lb, k=100 lb per inch, $\xi_2=0\cdot01$, $\xi_1=0\cdot01$, $v_c=0\cdot74$in per second.

II—W=5 lb, k=100 lb per inch, $\xi_2=0\cdot01$, $\xi_1=0\cdot1$, $v_c=0\cdot316$in per second.

III—W=10 lb, k=50 lb per inch, $\xi_2=0\cdot01$, $\xi_1=0\cdot01$, $v_c=1\cdot47$in per second.

IV—W=10 lb, k=50 lb per inch, $\xi_2=0\cdot01$, $\xi_1=0\cdot1$, $v_c=0\cdot625$in per second.

Table I—*Observations* ($v-\delta$)

	δ(in $\times 10^{-3}$)			
v in/sec	I	II	III	IV
0·0052... ...	4·70	4·11	19·20	16·40
0·0094... ...	4·90	3·94	19·20	16·80
0·0167... ...	4·60	4·00	19·10	16·80
0·0334... ...	4·70	4·12	19·60	16·20
0·054	4·75	3·94	19·50	15·80
0·067	4·90	4·00	19·20	15·70
0·083	4·70	4·15	19·60	16·00
0·106	4·65	4·02	19·70	16·20
0·130	4·70	4·16	19·80	15·80
0·167	4·60	4·00	19·80	15·70
0·219	4·78	3·65	19·70	15·60
0·280	4·60	2·20	19·60	15·60
0·345	4·45	—	19·80	15·20
0·427	4·38	—	—	—
0·535	4·25	—	—	—

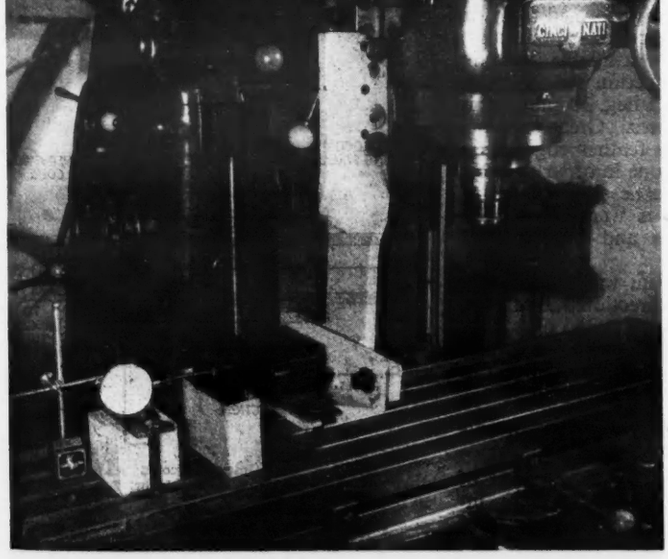

Fig. 5—Experimental stick-slip apparatus operated on a milling machine

Discussion of Results and Applications to Practice

Theoretical and experimental results for the sensitivity parameter represented in Fig. 6 reveal the following :

The parameter $\left(\frac{\delta}{\Delta F/k}\right)$ is generally close to 2 for the small damping usually obtained in practice. Increase of damping to very high values would improve sensitivity; though the damping ratio ξ' in its usual range obtained in practice, 0·001 to 0·1, does not seem to influence sensitivity to that extent.

Sensitivity increases very slightly with the velocity of shifting, up to 50 per cent of the critical, while it increases rapidly for (v/v_c) more than 50 per cent.

The main variables to influence the sensitivity are ΔF and k. Thus sensitivity as well as the error of shifting can be increased by increasing the stiffness of the flexible system and by decreasing the difference between the static and kinetic frictional resistances.

The agreement between observed and theoretical values of $\left(\frac{\delta}{\Delta F/k}\right)$ appears to be good (within 7 per cent) throughout the speed range, particularly at lower velocities ($v/v_c<0\cdot5$).

It should thus be clear from the foregoing that the stiffness of the drive should be as high as possible in order to improve sensitivity. It is quite evident that ordinarily a springy drive introduces a time lag. Thus in machine tool drives, the motion of the machine slide is always lagging behind the corresponding instruction given to it by the drive motor. Such time lag results in dimensional errors in workpiece. For instance, if

the time taken by the table to receive a response from the drive motor is 1/50 second then at a traverse speed of 30in per minute, a dimensional error of 0·01in would result. It is thus necessary to ensure adequate stiffness throughout the drive. It is desirable, for instance, that the lead screw, the thrust and journal bearings, together with brackets and other components in which these bearings and the nut are housed should be of sufficient stiffness. Similarly, the lower speed drive gears must be of sufficient pitch, face width and of good tooth profile in order to reduce tooth deflections to a minimum. Again, the rigidity of table, cross slide and bed casting also affect the accuracy of slow shifting.

Requirements for provision of high rigidity in the drive can be considerably minimised by reducing the amount of work the drive has to do. This can be achieved by reducing frictional forces in important places. Substantial reductions can be achieved in the effort that the screw has to impart to the table, by reducing the friction of the sideways, such as by the use of roller guides. However, in the case of roller guides, the problem of obtaining the requisite accuracy (fifteen-millionth of an inch, without excessive manufacturing cost) and also the problem of protection from ingress of dust should be looked into. Further, if the slide is driven by means of a screw and nut, the latter can be made of the ball recirculating type. And finally all the rotating members of the drive can be mounted in anti-friction bearings.

Another important factor that has a bearing on sensitivity is the damping in the system, as shown by Fig. 4. Although damping does not have an appreciable effect on the natural frequency of the system, it may be noted that any increase of damping will increase the sensitivity by suppressing the tendency towards oscillations.

In the case of servo-mechanism controls, viscous damping may sometimes be added on the output shaft to improve the damping, but this has the disadvantage that large losses are incurred which will greatly increase the size of the servo-motor.

Finally, it should be pointed out that the sensitivity can be considerably increased by reducing ΔF, the difference between the static and kinetic frictional forces. This may be done by reducing friction such as by using rolling friction instead of sliding friction. Boundary friction may, of course, be also reduced by using lubricants with suitable polar additives.

Acknowledgment

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Mass Flow and the Mixing Process in Low-Velocity Air Ejectors

By PROFESSOR L. J. KASTNER* and DR. J. B. McGARRY†

Although the ejector is essentially a simple device, it can work over an extraordinarily wide range of conditions, and theoretical analysis, though apparently simple enough at the outset, is likely to become very lengthy and intractable when it is desired to evaluate performance factors which may be of special importance in a particular case. When the "suction" and "forcing" fluids are different in character, or when there is a change of state in the ejector, the analytical problem becomes still more difficult as is witnessed by a real scarcity of reliable literature. However, whilst the simpler problem, that is to say the one concerned with ejectors in which there is no change of state and in which one fluid only is involved, has been attacked with some success, it is evident that further experimental work will also be valuable here both because it will extend the boundaries of existing empirical knowledge, and because it will provide additional facts with which theory may be compared. The immediate aims of the work described below were to obtain information about air ejector performance when the forcing air velocity is very low—of the order of 100ft or 200ft per second or less—and to re-examine certain conclusions about the best mixing length which had previously been published. For this latter examination, higher forcing velocities in the range 1000ft to 1500ft per second were used.

Apparatus

THE apparatus used for the low-velocity experiments is illustrated in Fig. 1 (*a*). Since, for these experiments, a greater steady mass-flow of forcing air was desired than could be provided by the compressor, two ejectors, *A* and *B*, were employed in "cascade," the total delivery air flow from the first providing—after it had flowed through a straightening pipe—the forcing air flow for the second. In this way the forcing air for the second ejector system could be supplied at velocities up to about 250ft per second and its rate of flow varied up to a maximum of some 20lb per minute, several times the capacity of the compressor. The compressor delivered air at about 100lb per square inch gauge to two reservoir tanks from which it was discharged to the first, or "upstream" ejector. The flow to the ejector from the tanks was regulated by a control valve.

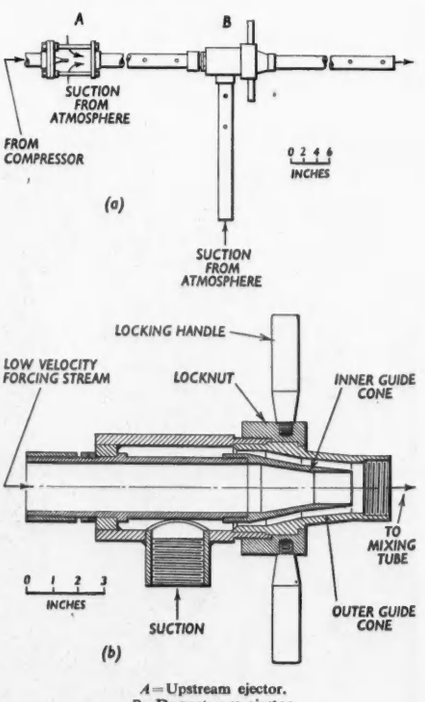
The second, or "downstream" ejector is illustrated in Fig. 1 (*b*).

The area ratio, that is to say the ratio of the area of cross section of the parallel mixing tube to the smallest area of cross section of the central forcing nozzle, was for these experiments kept at a constant value of 2·0 to 1. The suction stream was directed through an annular passage formed from the space between two guide cones. Guide cones of different slopes were available enabling the inlet angle of the suction stream to be varied from 10 deg. to 2 deg. 30 minutes in steps of 2 deg. 30 minutes. Great care was taken to ensure a clean feather edge at the end of the inner guide cone in order to avoid the formation of disturbances in the stream, and special arrangements were devised for ensuring that all pipes and nozzles were truly co-axial.

A traversing mechanism was provided to enable a complete unidirectional Pitot traverse to be carried out across the pipe cross section at selected stations, this mechanism permitting positional changes of the order of 0·004in to be made and measured.

Determination of Mean Velocity of the Air Streams

With the aim of reducing the amount of experimental work, it was decided to investigate a method recommended by von Aichelen for finding the mean velocity at a cross section by making a single measurement only, thus rendering it unnecessary always to conduct a complete Pitot traverse of the cross section. According to von Aichelen, a velocity measurement made at any cross section at a distance from the pipe axis equal to 0·762 times the pipe's radius will give the mean velocity at that cross section, provided turbulence is fully developed, at least within the range of Reynolds numbers from 4×10^3 to $3\cdot24\times10^6$. In the case of smooth pipes the greatest deviation from the mean value was less than 1 per cent, whilst for rough pipes the maximum deviation was 2½ per cent only. Von Aichelen obtained this result from detailed studies of his own work and by examination



A=Upstream ejector.
B=Downstream ejector.

Fig. 1 (*a*)—Ejectors in cascade (*b*) Section through downstream ejector.

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of the work of several other experimenters, including Stanton and Nikuradse. In view, however, of earlier work by Darcy and Threlfall which did not appear to agree closely with von Aichelen's conclusions, a series of check experiments was undertaken. In these check experiments it was observed that the value of the radial distance at which the measured velocity equalled the mean velocity of flow was approximately constant for all velocities and pipes examined, in conformity with the conclusions of von Aichelen, but the mean value of this radial

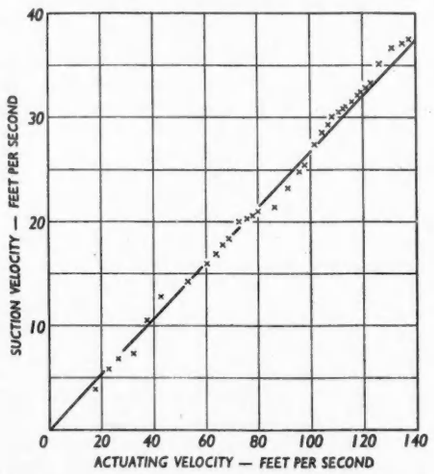


Fig. 2—Typical relationship between actuating and suction velocities. 2½ deg. mixing angle

distance was found to be 0·74× the pipe radius, instead of 0·762× radius, as given by him.

In the trials described below, suction and forcing velocities were measured at pipe cross sections close up to the downstream ejector, ample lengths of flow-straightening pipe being provided between the upstream and downstream ejectors and between the atmosphere and the suction branch of the downstream ejector.

Mixing Experiments for Low-Velocity Flows with Ejector of Constant Area Ratio

In these experiments the area ratio of the downstream ejector was kept constant at a value of 2 to 1, and the forcing velocity was varied from zero to a maximum of about 200ft per second. As mentioned previously, guide cones of different angles enabled the inclination of the suction stream to be altered. The main object of these trials was to determine the variation of the induced flow with the forcing flow, for the low forcing velocities mentioned above, and Fig. 2 is a typical diagram showing the relationship between suction velocity and actuating (forcing) velocity for a mixing angle of 2½ deg. Similar diagrams were obtained for other mixing angles and it did not appear that the mixing angle had very great significance in these tests.

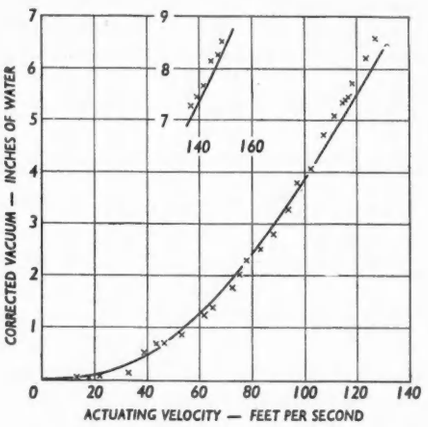


Fig. 4—Corrected terminal vacuum versus actuating velocity. 2½ deg. mixing angle

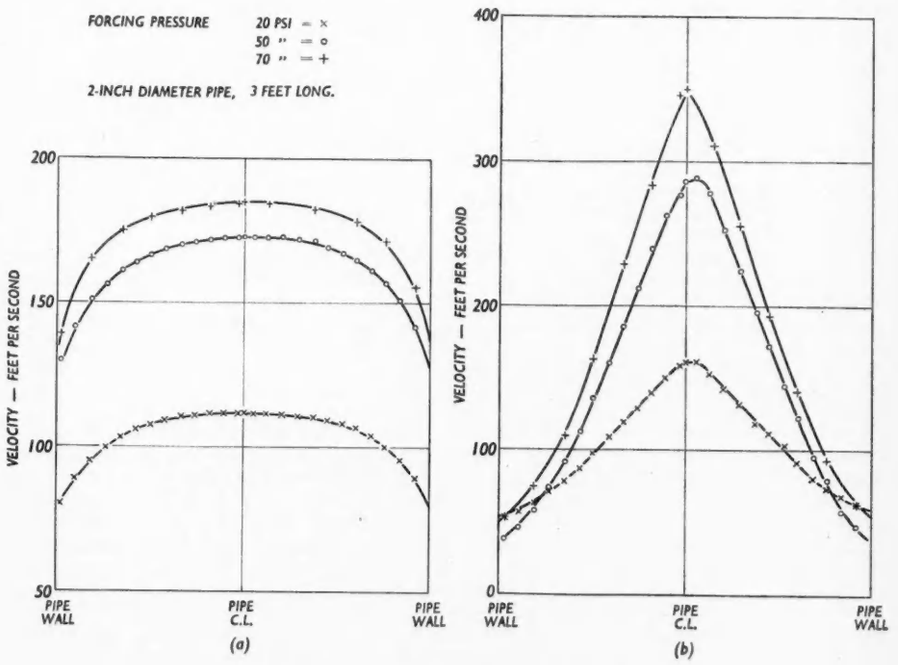
It was observed that, over the range explored, there was very nearly a straight line relationship between actuating and suction velocities. The theory of Weeks, supported by the experiments of Moos and those of Berry, Brombaugh, Moulton and Shawn, suggests that for an ejector operating under fixed resistance conditions the mass ratio of the total flow to the actuating flow remains constant for changes in the forcing velocity. Assuming constant density throughout, as applies very closely in the trials under review, this indicates that the mean velocity of the induced flow should vary in direct proportion to the mean velocity of the forcing fluid. By logarithmic plotting of results obtained in the present series of experiments, it was established that the relationship was more precisely $v_s = \kappa v_a^x$ where v_s and v_a are suction and actuating velocities. The values of the factor κ and the index x are to some extent dependent on the cones used. The mean value of x over the range explored was 1·07. The above relationship, however, will not in general correspond to the best performance obtainable with any particular actuating velocity. Optimum performance depends greatly on the proper choice of area ratio for the operating conditions which apply.

Fig. 3 shows the ratio of the suction mass flow to the actuating mass flow, plotted against the ratio of delivery pressure to suction pressure. For the 2½ deg. mixing angle, it will be seen that this mass ratio, and hence the ratio of total flow to actuating flow, is approximately constant.

For the 7½ deg. mixing angle, however, there was some decrease in mass ratio for the smaller pressure ratios and some increase for the larger ones, relative to the performance with the other angles tested. It will be noted that the pressure ratios are themselves very small, as would be expected for such small forcing velocities.

The ratio between delivery and suction pressure which is obtained when the suction flow is reduced to zero can be a valuable guide to the limits of performance of a given design. To determine the so-called " terminal vacuum " for the low-velocity experiments, a plug was screwed into the suction pipe inlet and sealed to prevent any suction flow. Variation of terminal vacuum with changes of forcing velocity was measured for the same mixing angles as had prevously been employed, and a typical result is shown in Fig. 4.

It was established that the terminal vacuum and the actuating velocity were connected by an expression of the form $S_t = \kappa' v_a^y$ where S_t is the terminal vacuum, κ' is a factor and y is an index depending on the



(*a*) Velocities measured at cross section 3in from exit
(*b*) Velocities measured at cross section 3in from entrance

Fig. 5—Transverse velocity distributions

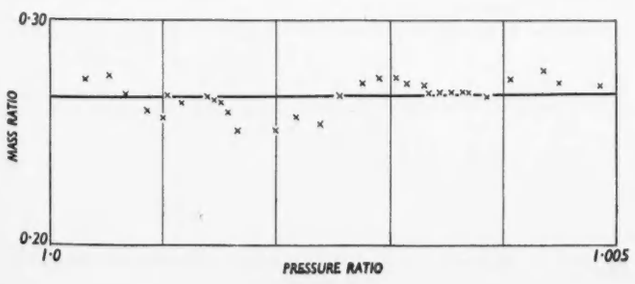


Fig. 3—Mass ratio versus pressure ratio. 2½ deg. mixing angle

angle of the guide cone tested. The values of y were 2·14, 2·26, 2·30 and 2·23 for the 2½ deg., 5 deg., 7½ deg. and 10 deg. cones respectively, and thus the experiments substantiate for small actuating velocities the results of McElroy, who states that the vacuum varies directly with the square of the jet velocity for operating conditions in which the volume flow is proportional to the jet velocity.

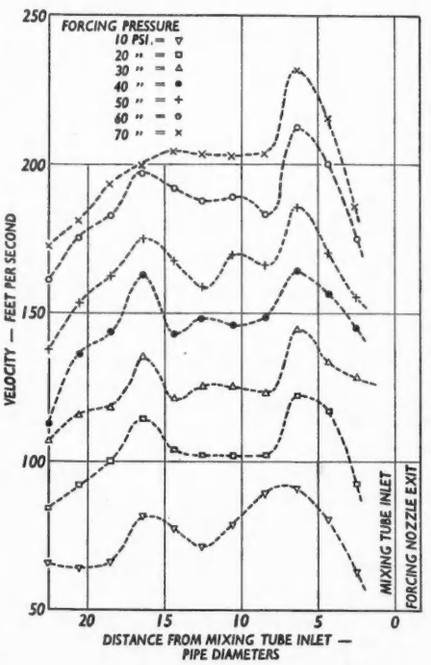
Some experiments were carried out with the suction flow heated electrically. The heat input to the suction stream was varied in a series of steps, the maximum temperature rise above atmospheric temperature (52 deg. to 62 deg. Fah.) being some 200 deg. Fah. Under these conditions it was found that the mass ratio varied very little from the value which applied to conditions when the suction stream was at atmospheric temperature, though the volume ratio increased up to 30 per cent or more.

This result may be compared with that obtained by Moos (loc. cit.), who heated the forcing stream and stated that the mass ratio then varied in proportion to the square root of the ratio of the absolute temperatures of the forcing stream to the suction stream.

Mixing Experiments with Flows of Higher Velocity

In order to study more conveniently the rate at which the mixing process progresses as the forcing and suction streams come into contact, it was decided to carry out velocity traverses across the mixing tube for conditions in which the velocities were appreciably higher than in the previous experiments. The use of these higher velocities made it somewhat easier to take the necessary readings, and increased experimental accuracy. The forcing flow, however, was now reduced in quantity, being limited, under steady conditions, to the maximum delivery through the actuating nozzle of the "upstream" ejector, this nozzle being of 0·185in diameter only. For these experiments the "downstream" ejector was removed, and the upstream ejector was modified in order to permit of different area ratios being employed, a wide range of parallel-sided mixing tubes of different diameters and lengths being available. The distance between the downstream end of the forcing nozzle and the entrance to the mixing tube could be varied, and for purposes of comparison was usually set to give maximum mass ratio.

Typical unidirectional velocity traverses are shown in Figs. 5 (*a*) and 5 (*b*), for a 2in diameter mixing tube 3ft in length, the three curves in each diagram corresponding to forcing pressures of 20 lb, 50 lb and 70 lb per square inch gauge respectively. Fig. 5 (*a*) applies to a case where measurements are taken at a cross section near to the discharge end of the mixing tube, whilst Fig. 5 (*b*) applies to a section near the entrance. In the latter case, a central core of high velocity is observed, with low velocities in the neighbourhood of the boundary walls, whilst in the former case (near the exit) the velocity distribution across the cross section is much more uniform, indicating that the forcing and suction streams are thoroughly mixed. It is interesting to observe, in Fig. 5 (*b*), a tendency for the velocity near the walls to be higher for a lower forcing pressure than for a higher one, which suggests that mixing is further advanced at the cross section considered for the smaller forcing velocity corresponding to the lower pressure.



Velocities measured at 0·133in from pipe wall

Fig. 6—Longitudinal velocity distributions

With the object of obtaining a sufficiently detailed picture of velocity distribution throughout the whole length of the mixing tube, traverses were made at a number of cross sections spaced along the length of the mixing tube and the velocity at a constant small distance from the pipe wall was noted. Though this distance was small it was not small enough for velocity measurements to be rendered inaccurate by boundary effects.

In this way the cross-section at which the velocity at a small fixed distance from the wall attains its maximum value was determined and it was considered that this was the cross section at which mixing was complete for the given tube arrangement. A typical diagram is shown in Fig. 6, from which it appears that the velocity close to the wall (at a distance 0·133in from it) reaches a maximum value at between six and seven diameters from the tube entrance. The diagram applies to a range of forcing pressures from 10 lb to 70 lb per square inch gauge and exhibits two quite well-defined peaks, the first occurring between six and seven diameters from the entrance and the second about seventeen diameters from the entrance. The second peak is lower than the first and was not observed for a forcing pressure of 70 lb per square inch gauge, though it was present for the other forcing velocities which were used.

The experimental results shown in Fig. 6 apply to a mixing tube of 2in diameter and 44in long, and similar diagrams were obtained for shorter tubes which were tested in order to examine the influence of wall friction. For these tests forcing pressures of 20 lb, 40 lb and 70 lb per square inch gauge were considered sufficient since it was found that differences in forcing velocity did not produce significant differences in the form of the curves. Analysis of all the results obtained revealed that a mixing length of about seven diameters was required for mixing to be complete, which is in good agreement with the value given by Engdahl and Holton, who approached the problem in a different manner. However, it appears that the length required for complete mixing may, under certain circumstances, not give the greatest induced mass flow. It was considered that the apparatus available for the present tests did not permit of a sufficiently accurate check of this point.

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LETTERS AND LITERATURE

Letters to the Editor

SCREWY SCREW THREADS

SIR,—Your July 15 leading article on screw thread difficulties contains the statement :

"... it is also becoming widely appreciated that the old British standard fine thread is decisively preferable in certain respects to its nearest unified counterpart."

This is very true and many engineering organisations in this country now face a dilemma. Until about ten years ago a body of successful practical experience had been built up with the British Standard Fine Thread. When, now, it is necessary to meet a customers specification of Unified threads, the question is : To go finer, to Unified Fine, or to go coarser, to Unified Coarse ? There seems at present to be no clear general answer but an impression arises from the somewhat bewildering evidence on the subject that Unified Fine is a thread to be avoided.

Being aware of this perplexing situation, the British Standards Institution is taking the praiseworthy step of adding a technical appendix on the strength of screw threads to its revision of Specification No. 1580 : 1953, Unified Screw Threads. Unfortunately, this specification revision is still only in draft form and even when the revised specification is issued, much of the difficulty of decision is likely to remain.

Your leading article points to the economic or organisational problems associated with changing over or duplicating thread stocks. It does seem, however that difficult though these problems are, they are straightforward by comparison with the general one of deciding what is the best screw thread for a given application. The attached graph highlights the question : What are all the factors—in elastic theory, workshop mechanics, psychology, many other divisions of science and art—which combine to make no thread so relatively fine as a large diameter Unified and no thread so relatively coarse as a small diameter Watchmakers' ?

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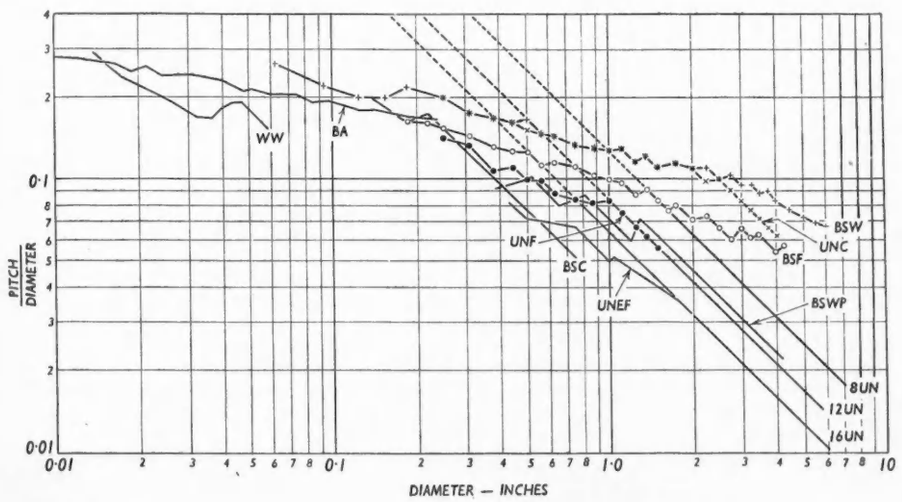
July 20, 1960.



× UNC—Unified Coarse.
● UNF—Unified Fine.
UNEF—Unified Extra Fine.
8UN—Unified 8 t.p.i. series.
12UN—Unified 12 t.p.i. series.
16UN—Unified 16 t.p.i. series.

+ BSW—British Standard Whitworth.
○ BSF—British Standard Fine.
BSC—British Standard Cycle.
BSWP—British Standard Whitworth (pipe).
BA—British Association.
WW—Waltham Watch (American).

Standard Screw Threads

STRUCTURAL STEELWORK AND BRITISH STANDARDS

SIR,—It is, I fear, quite impossible to argue logically with Messrs. Proctor or Tuplin, as they appear to have made up their minds that the British Standards Institution is an all-powerful and even somewhat sinister organisation which seeks to foist unwelcome standards on to an unwilling industrial public.

These two of your correspondents must know that the B.S.I. exists only as the sum total of the thousands of British firms and organisations who support our work, financially and possibly more important in the present context, the 18,000 men and women who actually write British Standards as members of our technical committees. If these knowledgeable and authoritative people decide to incorporate in a British Standard what Mr. Tuplin regards contemptuously as " helpful " information, one is surely safe in assuming that the information really is helpful in the best sense. In any case, as I said in my earlier letter, no one is under any obligation to use British Standards.

In specific reference to structural steelwork will you allow me to quote from a recent issue of the New Zealand journal *Engineering*. It contains an official report of the failure during construction of the twin-girder steel framework for a New Zealand highway bridge. This report concludes with the following statement :

"... it would appear that B.S.153 and B.S.449 give the most realistic permissible working stresses for steel beams in bending. More than this, however, the clear distinction between working stresses and critical stresses makes it possible to estimate erection overstress with complete confidence. ... It has been decided by the (New Zealand) Ministry of Works that in the future, permissible working stresses for steel beams in bending will be calculated from B.S.153 or B.S.449."

G. WESTON,
Technical Director,
British Standards Institution,
2, Park Street, London.
July 22, 1960.

DISTRIBUTION OF SHEAR STRESS IN A BOX BEAM

SIR,—Mr. Heath, in his letter published on July 15, expresses interest to know which branch of engineering should so flagrantly trangress the laws of elasticity as to assume equal shear stresses in the webs of a box beam. In the design of reinforced concrete structures many sweeping assumptions are made, one such being the assumption in a beam subject to bending and shear that the concrete below the neutral axis is cracked yet may sustain shear stress.

No reference was made in my article to the papers quoted in Mr. Heath's letter because the calculations were, in fact, performed independently, although reference should have been included to the standard work *Theory of Elasticity* by Timoshenko and Goodier, published by McGraw-Hill Book Company, which discusses the bending of prismatical bars at some length.

B. A. WALKER.

Westminster, S.W.1.
July 22, 1960.

LAST SOUTHAMPTON PADDLE STEAMER

SIR,—It is difficult to believe that Mr. J. H. Jellett, commenting in your issue of July 1 on Mr. G. W. Tripp's article of June 10 under the above heading, could make such a fundamental error as to describe the D.E.P.V. " Farringford " as a paddle steamer. It is quite obvious that Mr. Jellett is no admirer of these lovely craft.

I think that the matter is summed up neatly in a previous article, " The Survival of the Paddle Boat," by G. W. Tripp which appeared in THE ENGINEER some six or seven years ago, in which he referred to the external similarity of the Clyde D.E.P.V. " Talisman " to a paddle steamer, a similarity which terminated abruptly at one's first sight (and smell) of the so-called engine-room, which he described as a " hollow mockery " !

WM. C. BUDD.

Rugby.
July 9, 1960.

LETTERS AND LITERATURE *(Continued)*

Book Reviews

Commercial Road Vehicles. By E. L. CORNWELL. B. T. Batsford, Ltd., 4, Fitzhardinge Street, Portman Square, London, W.1. Price 30s.

ART being elimination, as we are assured, one who has treated adequately the evolution of both goods and passenger vehicles in a mere 275 pages can claim to be an artist as well as, in this case, an expert and experienced engineer and editor. It should swiftly be made clear that elimination has been the fate principally of developments abroad that have not affected this country and of details which, much as they may appeal to specialists in this field, would be valueless to those seeking to understand the great forces moulding a vitally important industry. The characteristic virtue of this book is one that the author, in his capacity as technical editor of our contemporary, *Modern Transport*, would be quick to applaud in others, a fierce and dedicated economy in the use of words ; every clause conveys intelligence, and sufficient—just sufficient—explanation is afforded to render reading an exercise for the reasoning rather than the retaining powers. Consequently, this single volume encompasses a well-rounded account of the construction and use of every form of commercial road vehicle, the term " commercial " being used, as is commonplace, to include Hackneys only if of the usual public service vehicle passenger capacity. If the editing errs, it is in being eclectic ; " road " is stretched far to include tramways, but this is perhaps essential to allow the author to treat steam and electric traction in a balanced manner and to cover " trolleybuses " that are merely steerable trams.

The method used to explore the history of this thickly burgeoning field of endeavour has been to follow the more important system of the day, the horse in the eighteenth century, steam in the early nineteenth, and petrol from the late ninteenth up as far as that crucial point, the Road and Rail Traffic Act of 1933.

The next two chapters treat, respectively, the development of diesel-engined and electric vehicles up to the present. Chapters VI and VII outline the histories of (British) heavy commercial vehicle manufacturers and of British light commercial vehicle manufacturers. The author then (like many designers) deals separately with coachwork and the " vehicle." The last two chapters complete the story of goods and passenger services from 1933 to 1960 and seek to show how it will read in the near future.

For a significant work of reference to come so closely up to date is obviously remarkable, and has not been achieved without there escaping excision one or two sentences more ephemeral than to be bound with the remainder of the text. To say that the " British motor industry collectively provides a more comprehensive range of vehicles than that of any other manufacturing country, and this applies as well to commercial goods and passenger vehicles as to the private cars " is of doubtful accuracy unless the Citroen, Cummins, Euclid, Goggomobil, Lambretta and Volkswagen designs made or assembled here are included. It is also somewhat inconsistent with the author's observation that certain technically advanced details are not found on British-designed vehicles and that none of the British " rigid " vehicles are stiff and well suspended enough to carry a bulk liquid tank, and his recording that operators are sometimes forced to build their own vehicles. The statement that " return loads are seldom carried " in " C " and contract " A " licence operation, followed by a reference to the Ministry of Transport survey of 1958, should surely have been supported by the findings of the study of a much larger sample in the following month by the Traders Road Transport Association ; this survey showed that " C " licence vehicles ran empty 17 per cent of their mileage, but more than half of this empty running was performed by vehicles, such as tippers, which would have difficulty in obtaining return loads even if legal restrictions were absent. The United States origin of the DPA pump is no more than implied by the statement that C.A.V., Ltd., developed it, and there is an unexplained allusion to a " shockfree" acceleration control system for trolleybuses.

It may be true that the main features of the original 6×4 Scammell are to be found in the " Explorer," but to say so does less than justice to the driving and braking of the steered wheels, and the ingenious epicyclic reduction trains that afford differential action on the present vehicle. Another vehicle with front-wheel drive is also given less description than it seems to deserve ; it is not said that before 1950 the Land-Rover had no need of provision to engage four-wheel drive because the front axle was driven through a free wheel. Placing emphasis on British practice has also allowed the further step forward by Ford, of using a lower gear ratio for the front wheels, to be overlooked. It may also be thought that the ease with which disc brakes can be fitted within drum wheels is optimistically assessed. One or two of the diagrams irritate ; " S.V" is a somewhat enigmatic style for the safety valve on the earliest British vehicle illustrated, Murdock's model of 1785, while the " heat sink " in the Wagner water-cooled disc brake system can only be identified speculatively as a reservoir on the downsteam (cold) side of the radiator.

However, the principal criticism of this book must be that the author has been so sparing of his hard-earned insight and judgment. The anomalies of the present maximum weight restrictions, such as equal limits for the twelve-tyred rigid and the fourteen- or eighteen-tyred articulated vehicles, are made clear, but there is no discussion of whether or not these regulations should be based on what the roads will stand, leaving it to operators to discover what the vehicle will attain, or of other possible limits such as tyre pressure or minimum time for a standing start quarter mile. The longing expressed for a " completely indestructible " paint that will last the life of the coachwork will be echoed widely, but the author is less ready to set targets for others than the petroleum chemist ; for instance, he cites the advantage of a reserve of power possessed by steam vehicles with other than flash boilers, but does not stress the objectionable practice of limiting automotive engines to outputs that can be sustained for very many minutes. A much more detailed study of the difference between " light " and " heavy " vehicles built since the 20 m.p.h. limit ended would have been valuable, and could well have led to a discussion of the validity of the existing 30 m.p.h. limit, since it is observed that the vehicles are generally designed for 50 m.p.h. or more. The quality of technical journalism in this country is assessed, but that of the research work of M.I.R.A. is not, although the former does and the latter does not function in a " fail safe " manner with respect to the industry !

The text is generously illustrated, the recent rallies of the Historic Commercial Vehicle Club having afforded opportunities to photograph several interesting specimens ; even when rather important and well-known vehicles are the subjects, unusual pictures have been sought. As is the custom of this publisher, a number of further illustrations appear on a very attractive jacket.

Sir Casimir Stanislaus Gzowski : A Biography. By LUDWIK KOS-RABCEWICZ-ZUBKOWSKI and WILLIAM EDWARD GREENING. Burns and MacEachern, 12, Grenville St., Toronto, 2. Price 4.75 dollars (Canadian).

WITHOUT undue over-simplification, the Dominion of Canada may be regarded as a product of the engineer. Only a few weeks ago, when the last steam locomotive was withdrawn from the Canadian National Railways, it was acknowledged that Canada has expanded " through the strength and power of steam " from small settlements to a thriving network of cities extending from the Atlantic to the Pacific. Mr. Garnet T. Page, the General Secretary of the Engineering Institute of Canada, draws attention in a prefatory note to this book that, " in the last century, as a transcontinental Canada waited to be born of the rail link between two oceans, it was a time when the engineer's destiny rode on the broad shoulders of outstanding individuals, whose personal standards have become a professional inheritance." There is, therefore, current value as well as historical interest in learning something of what were the personal (engineering) standards of the small group upon which the nation depended. One of the outstanding pioneers was the remarkable and colourful personality whose career forms the subject of the present volume.

Casimir Stanislaus Gzowski was the most notable and interesting immigrant from Central and Eastern Europe who settled in Canada during the nineteenth century, and few foreigners have played such a useful and influential role in so many spheres of Canadian life. He was born in Petersburg (now Leningrad) on March 5, 1813, the son of a Polish minor nobleman and officer in the Russian Imperial Guard. As might be expected, he was intended for a military career, and in 1830 he obtained a commission in the Imperial Russian Engineers. Participation with other officers of Polish descent in an insurrection of 1830-31 resulted first in military imprisonment, and then exile in 1833 to the U.S.A. Within four years of his landing, without knowledge of English and devoid of friends and resources, he had mastered the language, had become a U.S.A. citizen, had been admitted to the Massachusetts Bar, and built up a comfortable law practice. Soon, however, the call of the engineer asserted itself and he obtained congenial work under William Milner Roberts (1810-81) in an era of highway, turnpike, canal, and railway, construction. While representing his firm in Canada, he met Sir Charles Bagot (a diplomat friend of Gzowski's

father) and was appointed Superintendent of Roads and Waterways in the London district of Upper Canada (now Ontario). His work attracted the attention of Alexander Tilloch Galt, and he left Government service to become a railway contractor. Gzowski's railway activities form the subject of a fascinating chapter in which engineering and finance are intertwined almost inextricably. Some interesting details emerge about the relative positions of the British firm of Peto, Betts, Brassey and Jackson, and the Canadian contractors, Galt, Gzowski, Macpherson and Holton. In this respect, the present volume may be read profitably in conjunction with *The Grand Trunk Railway of Canada*, by A. W. Currie, published by the University of Toronto Press in 1957.

Gzowski and his partners did exceedingly well out of the Grand Trunk project, in spite of the fact that the company was in continual financial difficulties. There is no doubt that the profits from this enterprise formed the basis of the large personal fortune which was to make him among the most financially successful of the Canadian engineers of his time. It is noteworthy that Gzowski consistently pursued European engineering standards of solid construction rather than the U.S.A. practice of the period, which often consisted of flimsy pioneer work with the object of achieving something rapidly by cheap construction which could be improved or regraded when it was earning its keep—but sometimes was not. Probably Gzowski's greatest contribution to early Canadian engineering was his insistence on quality. Charles Hutton Gregory, in a report dated August 15, 1857, on the works of the Grand Trunk Railway, praised Gzowski's skill, and compared his work favourably with that of other contractors. A year earlier, Thomas Baring (the Grand Trunk chairman) had referred to Gzowski as "an experienced Canadian," a phrase which may be regarded as a sincere tribute to a Russian military engineer of Polish race, who has been an American citizen, and took British citizenship only on June 1, 1846.

Gzowski's principal railway works were the lines from Toronto to London, Stratford to Sarnia and Detroit, and Montreal to Island Pond. He severed his direct connection with Canadian railways before the increasing complications of finance were to bring many into disrepute, but retained his interest in railways to the end of his life. Mention may be made, however, of the Toronto Rolling Mills Company, in which he was a partner—the first plant in Canada to roll iron rails. It was in operation from 1857 to 1873, but closed with the change-over to steel rails. Gzowski was interested in the Canadian rights of Wiliam Henderson's process for refining steel, but there is no record of his making commercial application of it.

Among many important engineering contracts, one which is peculiarly associated with Gzowski's name is the construction of the international bridge between Buffalo and Fort Erie, in connection with which he consulted Washington Augustus Roebling. The first locomotive crossed the bridge on October 27, 1873. The authors deservedly devote a chapter to this triumph of perseverance, skill, and resourcefulness in the face of obstacles. The stone piers still stand, but the superstructure has been replaced to meet modern load conditions.

From 1873 Gzowski practised on his own account, and took an increasing interest in public affairs. Engineering, military affairs, education, finance, industry, and religion, were among the activities which made him a public character. In May, 1879, he was appointed Honorary Aide-de-Camp to Queen Victoria and received a knighthood in 1890. He was one of the founders of the Canadian Society of Civil Engineers, established on February 24, 1887, and since 1918 called the Engineering Institute of Canada. He served as President for three years from 1889 to 1891. Early in his presidential term he endowed the annual Gzowski gold medal for the best original paper read before the Society by a member, with the proviso that no award be made unless such paper "shall be adjudged of sufficient merit as a contribution to the literature of the profession." Gzowski died at Toronto on August 24, 1898. His engineering career and his personality deserve a full-scale biography, and the joint authors of this volume have done their work diligently. The text is fully annotated, and a comprehensive bibliography is appended. If in places the book savours of the academic exercise, and contains, for example, some genealogical details of limited appeal, most of these are grouped in appendices. The main work is a valuable contribution to nineteenth century Canadian history and to the part played by engineers in general, as well as a tribute to the career of an outstanding man.

Cemented Carbides. By Dr. P. SCHWARTZKOPF and Dr. R. KIEFFER in collaboration with Dr. W. LESZYNSKI and Dr. F. BENESOVSKY. Macmillan Company, 10, South Audley Street, London, W.1. Price £5 5s.

THIS book like its companion volume *Refractory Hard Metals* is based upon the book *Harstoffe und Hardmetalle* published in Vienna in 1953. For it the second half of the original book has been revised and extended with the assistance of a number of authorities in the light of the progress made during the past seven years in the technology of cemented carbides. The book opens with historical notes on the development of cemented carbides, and goes on to deal in detail with their technology, manufacture and testing. A series of chapters then deals with the mechanical and chemical properties of various compositions, including tungsten-free tool materials and carbide-free cutting materials. The concluding sections discuss the use of cemented carbides as wear-resistant materials and their applications to metal cutting. All sections are well illustrated and include comprehensive bibliographies which are of particular value to readers wishing to delve more extensively into the subjects.

Die Regelung in der Heizungs-, Lüftungs- und Klimatechnik. No. 18 of the T.R. Special Series. Berne: Verlag "Technische Rundschau," Hallwag, Berne, Nordring 4. Price S.Fr.5.80.

THE present issue No. 18 of the "Technische Rundschau" special series contains the lectures given at the Zurich meeting of SGA (Swiss Society for Automation) in December 1958. The six papers reprinted here deal with control problems in air-conditioning and in industrial heating plant, the interiors of buildings as part of the controlled system, pneumatic controllers for air-conditioning, and the accuracy of automatic air-conditioning control installations.

Elements des calculs d'interpolation. By DONATIEN COT. Publications Scientifiques et Techniques du Ministère de l'Air, No. B.S.T. 123. Paris: Magasin C.T.O.: 2, Avenue de la Porte-d'Issy, Paris (15e). Price Fr.4435.

"ELEMENTS of Interpolation" falls into two parts; the first deals with functions of a single variable, starting with the formulæ of Lagrange and Newton and goes on to those of Gauss, Stirling, Bessel, and Everett. The operators E and Δ are introduced. The applications of the various formulæ are discussed, as well as the possibilities of shortening the calculations, subtabulation, inverse interpolation, unequal intervals, numerical calculation of successive differences, numerical integration using finite differences, and the method of summation. The second part deals with functions of two and more variables.

Elementare Schalenstatik. By ALF PFLUGER. Berlin-Göttingen-Heidelberg: Springer-Verlag, Berlin-Wilmersdorf, Heidelberger Platz 3. Price DM.19.50.

"BASIC SHELL DESIGN" is intended to give the student, as well as the practising engineer, the fundamentals of the theory of shells. The four main sections are concerned with the membrane theory of surfaces of revolution, the bending moment theory of rotationally symmetrical loaded shells, and the membrane theory for cylinders. Equilibrium conditions and the differential equations for the general case are briefly discussed, the example quoted being the hyperbolic paraboloid under snow load. A further short chapter is devoted to the state of stress set up in a shell. The literary references and collection of formulæ given in an appendix will be found useful by many.

Wärme-und Stoffaustausch in Arbeitsdiagrammen auf Projektiver Grundlage. By WERNER MATZ. Berlin-Göttingen-Heidelberg: Springer-Verlag, Berlin-Wilmersdorf, Heidelberget Platz 3. Price DM.24.

IN perspective geometry there is a major theorem which establishes the relationship between a complete quadrilateral and the four harmonic points on a line. Similar relationships are derived in the cases of heat exchanges and material transfer such as occur in evaporation, distillation and diffusion. It is therefore convenient, as the author shows, to constrict temperature curves, enthalpy and entropy diagrams, &c., with the help of projective geometry, as is shown with the help of thirty-three worked examples selected from mechanics and chemical engineering.

Books of Reference

Road Note No. 25. Sources of White and Coloured Aggregates in Great Britain (1959). H.M. Stationery Office. Price 1s. 3d.—This booklet consists basically of three tables, which list sources in Great Britain of (i) natural road-stones which are distinctively coloured; (ii) white aggregates available in sizes above ¼in and (iii) white aggregates available in sizes below ⅛in. There is much demand for white aggregates for uses such as in zebra crossings, and the division between table (ii) and table (iii) corresponds roughly to differences in usage, table (iii) covering such applications as thermoplastic road-making materials.

Books Received

Similarity and Dimensional Methods in Mechanics. By L. I. Sedov. Cleaver-Hume Press, Ltd., 31, Wright's Lane, London, W.8. Price 105s.

The Other Side of the Moon. Translated from the Russian. By J. B. Sykes. Pergamon Press, Ltd., 4-5, Fitzroy Square, London, W.1. Price 10s. 6d.

Dictionary of Mechanical Engineering Terms. Eighth Edition. By J. G. Horner. The Technical Press, Ltd., 1, Justice Walk, Chelsea, London, S.W.3.

High Productivity in Heavy Engineering. By A. G. Thompson. Iliffe and Sons, Ltd., Dorset House, Stamford Street, London, S.E.1. Price 65s.

Reciprocals of the Integers from 1000 *to* 9999. By T. H. Redding. Taylor and Francis, Ltd., Red Lion Court, Fleet Street, London, E.C.4. Price 18s. 6d.

Evolution of the Workshop Micrometer

By C. St. C. DAVISON

One of the most remarkable trends noted in this century is the advance made in precise engineering work. Greater accuracy in workmanship means greater efficiency and reliability; thus it is the technologist's constant endeavour to obtain greater precision at less cost. The author explains how precise measuring was at first carried out by astronomers who for over 3000 years studied heavenly bodies without the aid of accurate instruments. It was not until instrument-makers of the early seventeenth century supplied them with suitable micrometers, which they attached to their newly-invented telescopes, that they were in a position to achieve some degree of progress. The author also shows how great engineers like Boulton and Watt, John Smeaton and Henry Maudslay were concerned with the development of micrometers which led to the construction of machinery as we know it to-day.

Astronomical Micrometers

ASTRONOMERS were very anxious to find a measuring instrument to fit to the telescope after its invention in Holland about 1608. By accurately measuring the diameters of the sun, moon and planets at various times they could arrive at conclusions about their movements. Sliding scales were tried with some success, including the one invented by Pierre Vernier and described in his treatise of 1631. Then William Gascoigne of Yorkshire fitted an instrument (*circa* 1638) embodying an adjustable screw which showed greater promise (see Fig. 1).

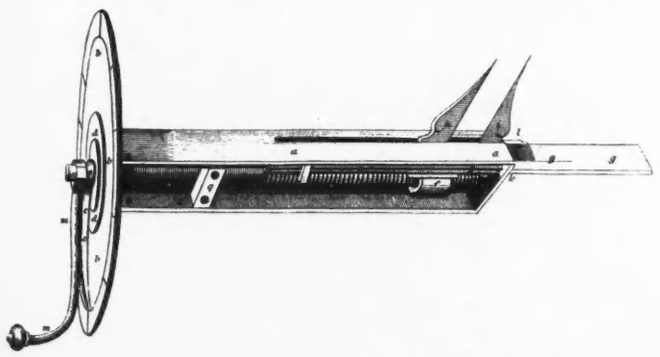


Fig. 1—Gascoigne's screw micrometer, 1639

At that time the accuracy of the screw depended entirely upon manual skill, for most screws were made from forged metal and worked into shape with handfiles. Machines for cutting metal screws were yet to be invented, although Leonardo da Vinci, Jacques Besson and Agostini Ramelli had shown drawings of machinery for making wooden screws on lathes in the sixteenth century.[1] For a long time, also, wire wrapped round rods and soldered in position was employed for making screws. The accuracy of Gascoigne's instrument, therefore, depended upon the manual skill of the screwmaker. It had a spindle with two threads cut on it : a fine one and a coarse one. The fine thread was employed for measuring and the coarse one, it is believed, was for keeping the parallel micrometer jaws centralised with the lenses of the telescope. A fixed dial at the end of the screw made it possible to measure small axial movements during one and more revolutions. In other words, a fine screw cut with accuracy and the dial graduated with care would have resulted in finer measurements than ever before being obtained. Thus it was possible for Gascoigne's screw with 30 t.p.i.* and the dial with 100 divisions to record a movement of the screw of 1/3000in.

* Threads per inch.

It is not known how successful Gascoigne's micrometer was, but it was improved upon during the next thirty years or so to the degree shown in Fig. 2. This is from Hevelius' book. He was born in Danzig in 1611 and wrote a new large catalogue of 1564 stars, He said that makers up to that time (1673) had not been able to invent and put together suitable machinery for the elevation and levelling of a telescope.[2]

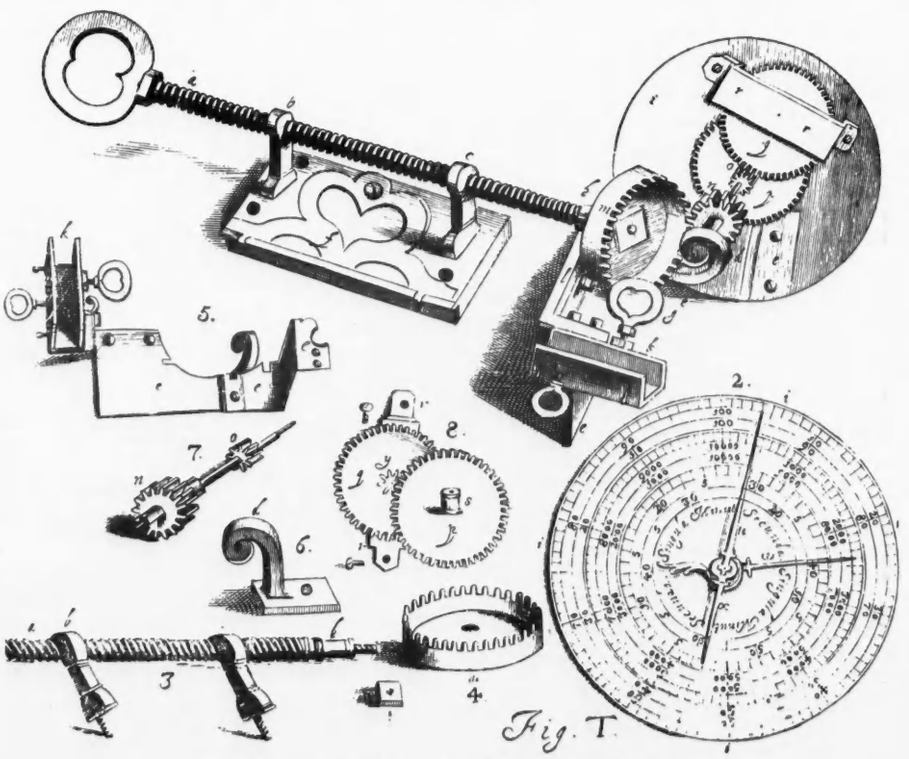


Fig. 2—From "Machina Coelestis," 1673, by Hevelius

Eighteenth Century Beam-Compasses with Micrometers

Progress was slow, however, according to present-day standards, and it was not until well into the eighteenth century that notable changes occurred in the field of measuring. Until then machines were made with little accuracy, but clock-makers developed the procedure of making geometrical drawings and of marking-off parts of clocks, and they constructed small hand-operated screw-cutting lathes with a lead-screw but no change-gears[3] (*circa* 1743).

It was felt in 1742 that for the better comparison of the results of experiments made both in England and France more accurate standards for measures of length—the yard and the metre—should be made to replace the old ones held by the authorities for all to see and to copy if desired. As a result George Graham made a yard-measure of much greater accuracy than the old standard made for Queen Elizabeth I. He took the yard-length from the old measure and marked it on his new one with beam-compasses. Then he continuously bisected the yard in order to obtain inches and fractions of an inch. His beam-compasses were made by an instrument-maker and they could be lengthened by means of an attached screw having 40 t.p.i. At the end of the screw was a disc with twenty divisions, which meant that each division gave a reading of 1/800in. But Graham wrote that each of these divisions could be further subdivided by eye into tenths so that the movement of the movable point could be judged to about 1/8000in. He found, however, that the hand and eye, aided by a magnifying glass, obtained consistent readings only with measurements of about 1/1600in. These remarkable compasses apparently are not preserved and it is necessary, therefore, to examine the micrometer arrangement on J. Bird's 23in scale of about 1758 in order to see the excellence of the screw which made possible such accurate marking-off (see Fig. 3).

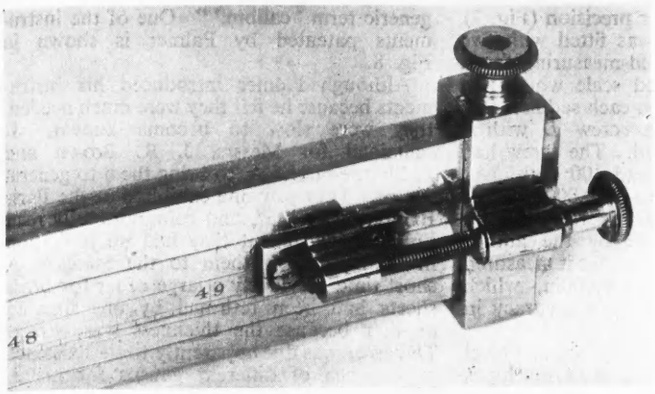


Fig. 3—Bird's 23in scale and vernier, *ca* 1758

The Invention of the Dividing-Engine

The influence of the improved screw upon astronomical readings was very noticeable. Up till the beginning of the sixteenth century few astronomical observations could be depended upon for accuracy to within less than five to ten minutes of arc ; by 1742 this was reduced to seven seconds or eight seconds, being an increase in accuracy of eighty or ninety times.

At the middle of the eighteenth century the graduation or "dividing" of straight lines or circles into any number of parts was still carried out manually with beam-compasses by mathematical instrument-makers. The first dividing-engine was, however, invented by Jesse Ramsden of Yorkshire in 1766 and the graduation process thus became easier and cheaper.

Fine measuring aroused so much interest that it was not surprising that Dr. W. Hunter stated before the Royal Society (1780) that he had invented a micrometer which read to 1/2,404,000in.[4] "The screw," he said, "is of all the mechanical powers the most commonly employed in performing motions of great accuracy." His instrument, shown in Fig. 4, had a screw *B* with both an external and internal thread. A male screw *A* operated inside the internal screw which had one thread more per inch than the external screw. Thus, when the main screw *A* was rotated and the smaller one prevented from rotating by its arms *F*, a differential axial motion was transmitted to the smaller screw *A*. As Hunter suggested : If the female screw *B* had 50 t.p.i. and the male screw *A* 51 t.p.i., and if *B* were revolved one revolution it would move forward in the nut 1/50in while the male screw would move backwards 1/51in. The relative movement, which would be indicated by the point *K*, would be 1/50in – 1/51in=1/2550in. He further suggested that if the circle at *ECD*, representing one revolution of *B*, be divided into eighty equal parts then one division would indicate 1/2550in by 1/80in= 1/204,000in. And as if this were not enough for precise measurement he added that by employing a magnifying lens he could further subdivide each division by ten, giving a reading of 1/2,040,000in. The latter was an exaggeration. He intended his instrument to be employed for measuring the diameter of a nervous fibre in the medullary substance of the brain.

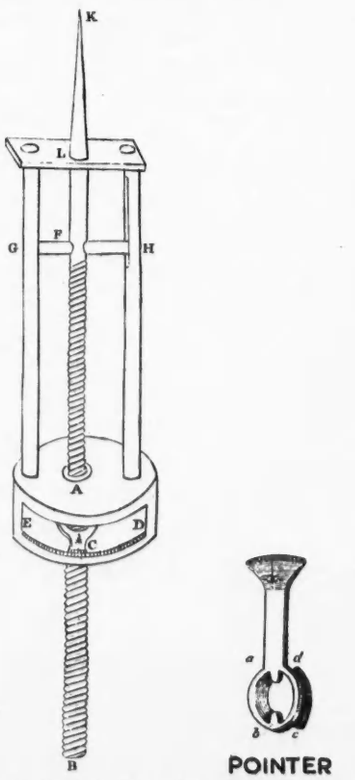


Fig. 4—Hunter's differential screw micrometer, 1780, to measure to 1/2·4 millionths of an inch

Precise Measuring Spread to Engineering

The advances made in linear and angular measurement, as we know, led to considerable advances in the exact sciences, and it was only to be expected, therefore, that they should have some effect on applied science. James Watt employed a micrometer-telescope combination while surveying in 1771. A workshop-micrometer believed to have belonged to him is shown in Fig. 5 (*circa* 1772). The "U"-shaped frame resembled the modern workshop-micrometer. Its screw (18 t.p.i.) acted like a pinion on a rack cut on a fixed bar on top of it. The dial fixed to the end of the screw had 100 divisions, thus reading to 1/1800in. Compared with Bird's micrometer this instrument was crudely made, but a recent test by the author showed that it was capable of measuring along its 1in range with an error varying between only −12/1000in and +2/1000in. The smaller dial apparently was for recording the number of revolutions made by the screw.

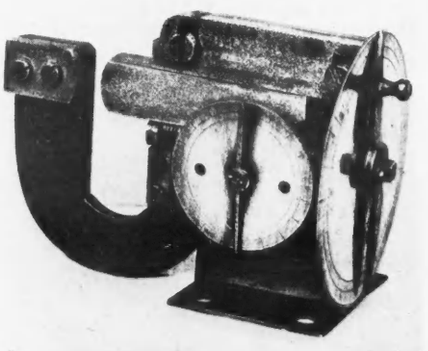


Fig. 5—James Watt's micrometer, *ca* 1772

When James Watt started building his Kinneil engine he was incapable of making a cylinder with accuracy (18in diameter by 60in stroke). He spent much time on his engine only to find, when it was completed, that the cylinder bore had an error between plus and minus $\frac{1}{8}$in, which he thought of hammering-out as the cylinder was of tin.[5] John Smeaton said that neither the tools nor the workmen existed who could construct so complex a machine with the necessary precision. Thus on the one hand we have Watt failing to attain his ideal, and on the other hand Smeaton indicating the dearth of skilled men and tools at that time when greater accuracy was realised to be of a prime necessity. Nevertheless, Watt's partner Boulton wrote in 1776 : "Mr. Wilkinson has bored several cylinders (cast iron) for us almost without error." John Wilkinson owed this success to a new machine which he constructed soon after the filing of his patent for a gun-boring machine (1774).[5] Thus the tin cylinder on the Kinneil engine was replaced by a more accurate one of cast iron.

This was a remarkable time. Mankind was on the verge of the Industrial Age ; the horologist and the instrument-maker had well-developed crafts and now the technologist entered the field, and with imagination and perseverance started to create an entirely new world. Some improvements were necessary, however. Screw-stocks and dies for making screw-threads in metal were still somewhat crude in design and workmanship and unsuitable for making large threads.

The Invention of the Screw-Cutting Lathe

The cutting-tool on the workshop lathe was moved by hand at that time. Most lathes were made almost entirely of wood, but Jacques de Vaucanson of France constructed an all-metal lathe, with a moving head which travelled longitudinally and transversely by means of manually-operated screws, between 1770 and 1790. It is preserved in the Conservatoire National des Arts et Métiers, Paris.

The talents of engineers which were given sway at that time reflected in the rapid advance of their trade. The accuracy of production had so far increased that in France efforts were made to introduce interchangeable parts for firearms. Workshop precision-measuring tools were therefore becoming a necessity.

Then François Senot constructed a lathe for screw-cutting (1795). It had a lead-screw for accurately moving the cutting tool, and changeable wheels for varying the type of thread it cut. It formed a basis for engineering accuracy.

Barton's Atometer

While he was Deputy Controller of the Royal Mint in London, Sir John Barton designed a micrometer (1806). It was called Barton's "Atometer," and can be seen in Fig. 6. The brass spindle (1in diameter) had two right-hand threads at *A* and *B* : one 90 t.p.i. and the other 100 t.p.i. Each of these screws operated a cup-shaped anvil *C* and *D*. When the wooden drum *E* was turned one revolution according to the calibrated portion, one anvil moved relative to the other a distance of 1/90in−1/100in=

1/900in. Since there were 100 equal divisions on the periphery of the drum, each division indicated a measurement of 1/90,000in.

In a letter which Barton addressed to Matthew Boulton in 1806 he stated : " When I had perfected the apparatus to my lathe

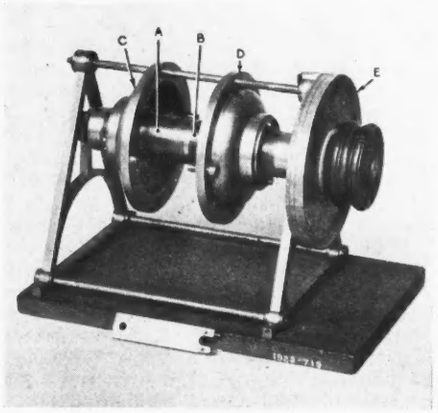


Fig. 6—Sir John Barton's " Atometer," 1806

for screw-cutting, I proposed to myself the pleasure of presenting to you a set of decimal screws, but you having mentioned the use to which you meant to apply the screw, induced me to direct my attention to the construction of an instrument for the purpose of measuring a right line into very small known parts, that is parts of an inch, or any given standard measure. I have constructed such an instrument . . . ." He said also : " Banknotes in thickness average about three turns of the screw or about 0·003in, and a bit of silver leaf which I have but roughly measured to-day seems to be about 0·00008in. Gold leaf I expect to find the thinnest of anything . . . . Even the 1/200,000th part of an inch is found to be a very sensible division."

It is not known how surprised Boulton was when he received the letter. The author wonders whether he noticed that although Barton had intended the instrument to read to 1/100,000in it actually read to 1/90,000in ; a curious error for so learned a man. The instrument is now in the Science Museum, London.

Maudslay's Micrometer

The skill of Henry Maudslay as a craftsman has been much admired. His lathe, which he constructed about 1800, was of advanced design and was capable of cutting screws of the highest accuracy. He made

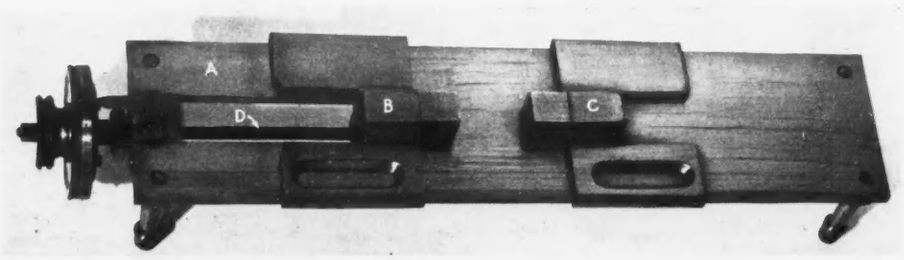


Fig. 7—Maudslay micrometer, 1805

astronomical dividing-scales with divisions so fine and small that they could only be made visible by means of a microscope.[6] He improved the existing taps and dies and pressed for the systemisation of thread sizes in England. He made a micrometer to assist in obtaining greater precision (Fig. 7).

The gunmetal bed *A* was fitted with two saddles *B* and *C* with end-measuring faces. The bed had a graduated scale which was viewed through the slot on each saddle. One saddle was moved by a screw *D* with a measuring drum at its end. The screw had 100 t.p.i. and the drum had 100 divisions ; thus each division read to 1/10,000in. The micrometer had a measuring range up to 6in. A recent test made by the author revealed that throughout its range it measured with a mean error of 8/10,000in, which speaks volumes for Maudslay's accuracy in workmanship.

From then onwards the rate of technical development was rapid. New tools, machines and methods were regularly introduced as one improvement led to another. The increase in the number of skilled workmen and their interest in the new techniques brought about great social changes. The railways being a result of these applications spread far and wide and replaced primitive horse-transport.

The Prototype Workshop-Micrometer

The next step was the pocket-size workshop-micrometer as it is employed everywhere to-day. It was patented by

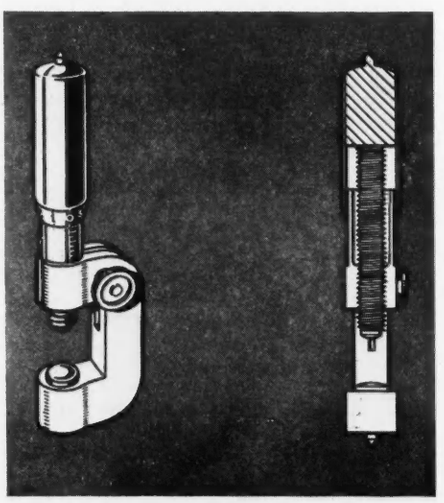


Fig. 8—L. Palmer's micrometer, 1848

Laurent Palmer in France in 1848 under the title : " *Un calibre à vis et à vernier circulaire.*" In the patent it was stated : " In commerce it is extremely necessary rigourously to determine the thickness of metal sheets in order to know their number. The instruments employed for this purpose hitherto are absolutely incorrect. The principle idea of my invention consists in employing the screw on tools known under the generic term ' calibre.' " One of the instruments patented by Palmer is shown in Fig. 8.

Although Palmer introduced his instruments because he felt they were much needed, they were slow to become known. It remained for Messrs. J. R. Brown and L. Sharpe of U.S.A. to bring them to general notice. They saw one exhibited at the Paris Exhibition in 1867, and being an easily read practical instrument they had no hesitation in taking it with them to the States.[6] A short time previously a large order for brass sheets had been returned by one firm to another because the thickness was wrong. The error was due apparently to the existence in America of different gauges for metal, which caused great confusion. Brown and Sharpe manufactured the micrometer with one or two minor improvements.

It is remarkable that although at first the micrometer was utilised as an astronomical accessory for one purpose only, it became indispensable for a variety of operations in the modern world when measurement has to be so exact. Indeed, very few workshops are found without it in present-day industry.

Acknowledgments

Acknowledgments are due to the Science Museum for permission to reproduce the engravings.

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Conference on Non-Destructive Testing in Electrical Engineering, November, 1961

The Measurement and Control Section of The Institution of Electrical Engineers, in association with the British National Committee on Non-Destructive Testing, is making arrangements for a conference on non-destructive testing in electrical engineering to be held at the Institution in London from November 8 to 10, 1961. The theme of the conference will be " How best may the electrical engineer test the quality and endurance of his materials and structures ? "

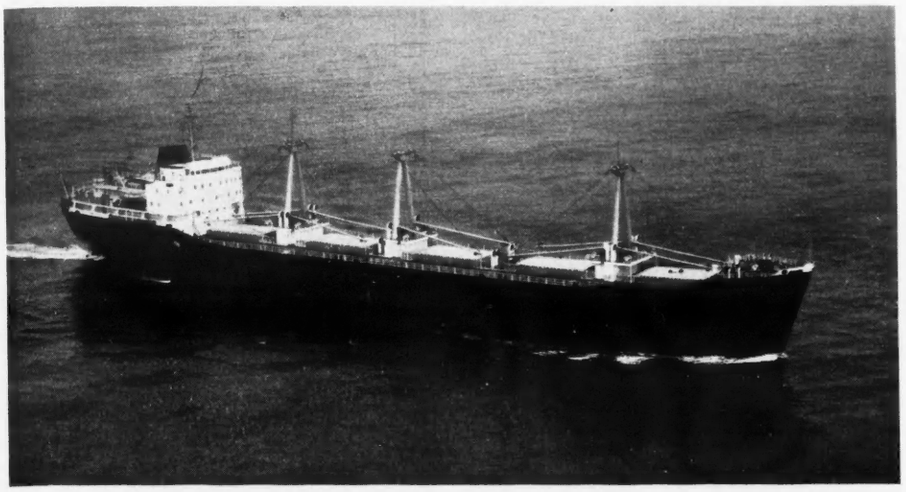
The conference will concentrate its attention on papers which deal with electrical methods of testing ; papers on the better-known methods of non-destructive examination, as used for the detection of defects in the materials and structures of civil and mechanical engineering, will in general be excluded.

The organising committee of the conference will be pleased to consider papers on the following and allied subjects : 1. Testing of materials—plastics, rubbers, laminates, glasses, ceramics, enamels, anodic coatings, papers, plastic foils, insulating liquids, metallic foils and magnetic materials. 2. Detection of impurities and inclusions in insulation. 3. Proof and maintenance tests on insulation, including measurement of discharge inception stress ; measurement of loss angle and conduction ; and overvoltage tests. 4. Detection of defects in insulators and bushings. 5. Electrical and mechanical tests on cables, cable sheaths and cable accessories. 6. Detection of concealed internal features, such as cable cores and potted components. 7. Testing of interfacial contacts and joints (electrical and mechanical). 8. Detection and damping of vibration. 9. Testing of thin insulating coatings on metals. 10. Detection and measurement of leaks in electrical equipment (gases, liquids and micro-organisms).

Full details regarding the procedure for the preparation of papers are available on application to the Secretary, The Institution of Electrical Engineers, Savoy Place, W.C.2.

Cargo Ship G.T.V. " Rembrandt "

The open shelter deck cargo ship " Rembrandt," which has an approximate deadweight of 12,900 tons, has been built and engined by Smith's Dock Company, Ltd., for the Bolton Steam Shipping Company, Ltd. A loaded service speed of 13 knots is maintained by propulsion machinery of 4000 s.h.p., consisting of five free-piston gasifiers and a non-reversing turbine driving a controllable pitch propeller through double-reduction gearing.



G.T.V. " Rembrandt " of 12,940 tons deadweight on trial

LAST year Smith's Dock Company, Ltd., installed free-piston gas turbine machinery in the cargo ship " Goodwood " in place of the existing steam machinery and an account of the conversion was given in our issue of April 10, 1959. This was followed by a report of the first eight months of operation of the installation which appeared in our columns in February 12 this year. The success achieved with the first set of this design of propulsion machinery has been followed by the construction of an installation of double the power and it forms the main propulsion unit for the open shelter deck cargo ship " Rembrandt," which can be seen in our illustration. This ship has been completed recently by the company to the order of the Bolton Steam Shipping Company, Ltd., and the ship, which has the machinery arranged aft, has the following particulars :

Length overall	491ft 9¾in
Length between perpendiculars	460ft 0in
Breadth moulded	63ft 0in
Depth moulded to upper deck	41ft 9in
Draught	27ft 8in
Deadweight	12,940 tons
Service speed	13 knots

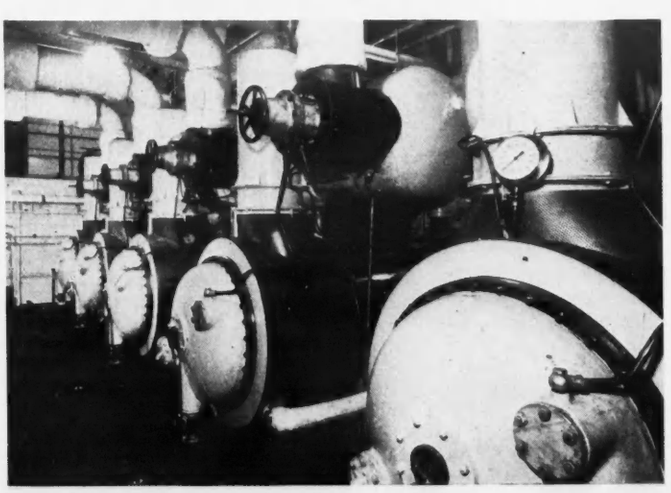
Cargo is carried in five holds served by six 5-ton and four 10-ton derricks rigged from three Bipod masts and operated by electric winches. MacGregor steel hatch covers are fitted at the weather deck. Two radial davits are mounted on the boat deck aft for handling stores, and also on the boat deck is a dinghy, a glass-fibre lifeboat of fifty-four persons capacity and a glass-fibre motor lifeboat of fifty-one persons capacity, both boats being carried in Schat davits.

Propulsion is by five free-piston gasifiers, one of which is a standby unit, which supply gas to a single-stage non-reversing turbine driving a controllable pitch propeller through a set of double-reduction locked train gearing. Using four gasifiers the machinery has a continuous maximum output of 4000 s.h.p. at 110 propeller r.p.m. and a maximum of 4400 s.h.p. for one hour. The weights of the main machinery components are as follows :

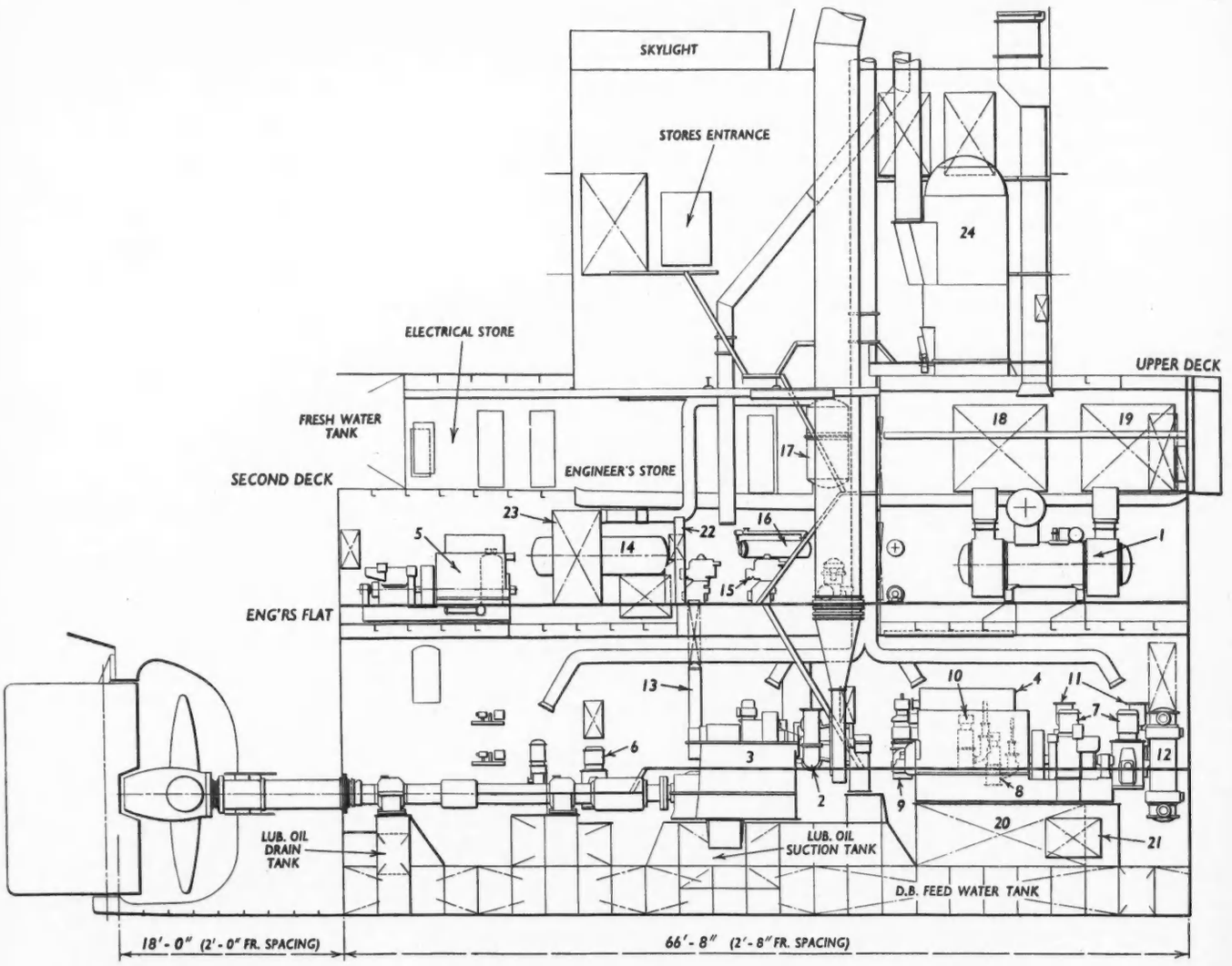
	Tons
Five GS.-34 gasifiers with recirculation	41·0
One gas turbine lagged and cleaded	6·0
One double-reduction gearbox and thrust block	30·15
One set of gaspiping and lagging	3·5
One control console	1·15
One set of blow-off piping and lagging	1·3
Weight of main machinery	83·1

The total weight of machinery including auxiliaries, stern gear, piping, tanks, spares and stores amounts to 420 tons. It is considered that the design of the machinery has made possible a compact engine-room to give a high power-weight ratio and a high power-bulk ratio. In addition to the direct saving in weight effected by the adoption of this design there is a saving in the length of pipe runs, a saving in steel for seatings and other savings which represent an addition to the deadweight of about 200 tons. The general arrangement of the machinery is shown in our drawing giving a longitudinal elevation of the engine-room. The short length of the machinery spaces has also meant an increase in the cubic capacity. Other advantages claimed for this form of propulsion are that maintenance is easier since the units are comparatively small and of light weight and so are easily handled, while losses due to total stoppage of the diesel machinery are eliminated since the ship can continue under way even should three of the four working gasifiers be out of action. The mounting of five gasifiers, illustrated herewith, provides for one to be overhauled and thus assures that the overall reliability will be high as will be the percentage availability of the machinery. The arrangement of the installation provides for any four working units to run in phase and so minimise intake and gas main pulsations and reduce the overall noise level.

Modifications based on research and sea experience gained from the " Goodwood " conversion installation have been embodied in the GS.-34 gasifiers which Smith's Dock Company, Ltd., has built under licence from Alan Munty and Co., Ltd. Each machine has been fitted with recirculation valves which enable them to match the turbine swallowing capacity over the pressure range and so avoiding blowing off gas when idling, and at the same time maintaining a low fuel consumption. With this device and under these conditions each gasifier develops 20 h.p., and it is possible to manoeuvre in restricted waterways. The gasifiers draw air direct from the engine-room through intakes of Smith Dock design, which ensure positive pressure in the inlet casings when the suction valves close. Furthermore, the gasifiers have been fitted with different combinations of liners and piston rings and these include : standard cast-iron rings and liners ; S.G. iron piston rings with special cast-iron liners ; cast-iron rings with a chrome-plated liner ; and chrome-plated S.G. iron rings and a special cast-iron liner. These combinations have been the subject of test bed experiments and it is hoped that the results will be confirmed by those attained in service at sea. Other refinements embodied in the gasifiers are a new design of stabiliser for rapid load changing, and solid forged manoeuvring pistons. At maximum continuous rating the designed gas delivery from the gasifiers is at 44 lb per square inch gauge and 869 deg. Fah. to produce 1230 gas horsepower per gasifier, the mean ambient temperature being 86 deg. Fah. Each gasifier discharges through an elbow pipe, fitted with gimballed expansion bellows, to a transverse manifold and the gas is conveyed to the turbine by two elbow pipes similarly fitted. The piping is made of chrome molybdenum steel while the bellows are of stainless steel.



Battery of five " G.S-34 " free-piston gasifiers on flat at forward end of machinery spaces



1—Smith-Pescara free-piston gasifiers.
2—Gas turbine.
3—Reduction gearbox.
4—Main diesel generators.
5—Auxiliary diesel generators.
6—Lubricating oil pumps.
7—Piston cooling oil pumps.
8—Diesel generator salt water circulating pump.
9—Bilge pump.
10—General service pumps.
11—Oil fuel transfer pumps.
12—Piston oil cooler.
13—Drain cooler.
14—Main air receivers.
15—Heavy oil fuel purifier.
16—Heavy oil purifier heater.
17—Oily bilge separator.
18—Lubricating oil piston cooling oil storage tank.
19—Cylinder oil storage tank.
20—Piston cooling oil suction tank.
21—Oil residue tank.
22—Control console.
23—Main switchboard.
24—Oil-fired boiler.

Elevation on centre line of ship looking to port

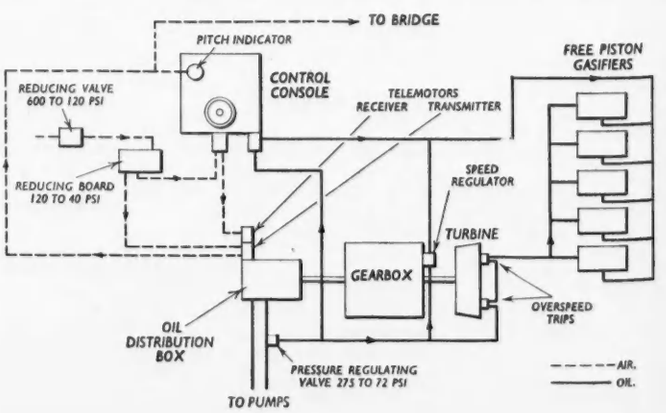
Turbine and Gearing

The six-stage, uni-directional reaction turbine built by The British Thomson-Houston Company, Ltd. at Rugby (now Associated Electrical Industries, Ltd.) has the following design performance :

Rating	One hour Overload	Maximum Continuous	
Number of gasifiers	4	4	3
Delivery pressure, lb per square inch gauge	46·7	43·1	26·4
Delivery temperature, deg. Cent. ...	482	462	365
Total mass flow, lb per second	34·7	33·1	24·3
Output at turbine coupling, h.p. ...	4600	4110	2000
Turbine speed, r.p.m.	7050	6800	5350

It will be noted from the above table that a pressure drop of 1 lb per square inch has been allowed in the gas piping and that efficiency of the gearing must be 97·5 per cent. The turbine inlet, outlet and exhaust casings are permanently bolted together so that dismantling is confined to horizontal joints. The inlet casing which is of carbon-molybdenum steel, consists of an inlet scroll, to which are welded two 14in diameter inlet branches, and a cylinder which carries the stainless iron stator blades and forms the outer part of the diffuser. Cast steel is used for the outlet casing which forms the inner part of the exhaust diffuser which ends with radial vanes welded between the casing and a steel ring bolted to the outer part of the diffuser. A fabricated pedestal supports the forward end of the casing while the after end is taken by the gearbox casing. The drum pattern rotor was machined from a 3 per cent chrome-molybdenum V.W. forging and the rotor blades, machined from stainless iron forgings, are inserted in circumferential grooves. A Michell thrust bearing having thrust and surge pads is located in the gearbox and the bearing housing carries an inlet bearing which supports the rotor, of which the other support is an outlet bearing in the forward pedestal. The turbine rotor thrust collar is nitrided and ground and in the event of failure of the main thrust bearing there is an emergency thrust bearing.

In the locked train double-reduction gearing, which has a fabricated steel casing, and was manufactured by the British Thomson-

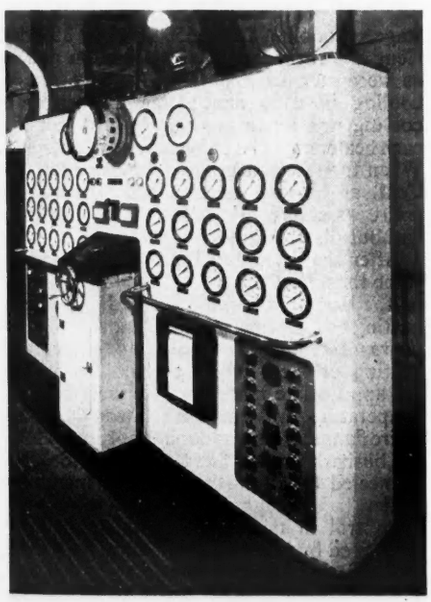


Diagrammatic arrangement of control oil and air pipes

Houston Company, Ltd., the turbine is directly coupled to the quill drive of the high-speed single-helical pinion which meshes with two single-helical wheels to make a first reduction from 6800 to 951 r.p.m. and divide the turbine torque in half. The two pinions of the second reduction, 951 to 110 r.p.m., drive one large double-helical wheel shrunk on to the output shaft. The turbine thrust is opposed by the thrust of the single-helical pinion, while double-disc thrust bearings take the thrust of the single-helical wheels and a similar pattern bearing absorbs the propeller thrust. The high-grade nickel chrome steel pinions are heat-treated and forged integral with the shafts.

Stone Marine Engineering Company, Ltd., manufactured the four-bladed Stone-Kamewa controllable pitch propeller, which has a diameter of 16ft 1in and is understood to be the largest produced in this country. The propeller, which was described in THE ENGINEER of December 11, 1959, is provided with a pitch trimming device which adjusts the pitch to suit varying conditions of loading and weather and the condition of the hull. Two Mirrlees pumps power the system and it is possible to reverse the propeller from full ahead to full astern in fourteen seconds.

Our illustration shows the control console



Machinery control console

which is centrally located in the engine-room and carries the main single handwheel controller. In the control system, of which we include a diagrammatic arrangement, the oil pressure regulating valve governs the oil pressure applied to the gasifier fuel racks and recirculation valves, the oil being supplied at 275 lb per square inch by the propeller oil pumps and bled at 72 lb per square inch to the gasifier system. The air pressure regulating valve forms part of the telemotor system controlling the propeller pitch control servo motor. A turn to right or left of the control wheel applies full ahead or astern pitch without affecting gasifier output, but two additional turns serve to increase the output from idling to a maximum. Another control ensures that power cannot be applied when reversing until the pitch change is complete. There are overstroke trips for the gasifiers, a low oil pressure trip and also an overspeed governor for the turbine. Operation of any one of these will stop the machinery by cutting off the oil supply to the gasifiers causing them to stop in one full stroke.

Electrical power is provided by two 200kW diesel-driven main generators and by two 75kW diesel-driven auxiliary generators. For treating diesel oil fuel, heavy oil fuel and lubricating oil there are a number of Alfa Laval purifiers of varying capacities. Hamworthy Engineering, Ltd., has supplied the ship's pumps, including a 65/113 tons per hour bilge pump, two 40/50 tons per hour ballast pumps, one 27/36 tons per hour general service pumps ; one 36 tons per hour diesel generator salt-water circulating pump ; two 180 tons per hour salt-water circulating pump ; two 140 tons per hour jacket water pumps ; two 65 tons per hour piston cooling oil pumps and two 24 tons per hour lubricating oil pumps. There are two 25 tons per hour Dawson and Downie oil fuel transfer pumps and several Serck coolers. Woods of Colchester, Ltd., provided two 38in diameter, 20,000 cubic feet per minute fans to ventilate the gasifier room and two 24in diameter 10,000 cubic feet per minute fans to serve the engine-room while to supply auxiliary steam at 100 lb per square inch there is an oil-fired Cochran boiler having 500 square feet of heating surface. There are two main air receivers, each of 60 cubic feet capacity supplied by two Hamworthy compressors, each rated to deliver 53 cubic feet of air at 600 lb per square inch.

On the test bed a gasifier fuel consumption of 0·326 lb per gas horsepower hour was attained, and the designed main machinery consumption of 0·40 lb per shaft horsepower hour is expected based upon estimated performance of turbine and gearing. On preliminary trials in ballast condition a speed of 14·58 knots was obtained and consumption of 0·428 lb per shaft horsepower obtained at 3870 s.h.p. This figure has yet to be verified and is expected to be improved upon after the gas ducting has been modified to reduce pressure losses and adjustments made to obtain more precise matching of the gasifiers and the turbine. A short test has been carried out using fuel of 1000 seconds viscosity and the heavy fuel installation is designed to handle fuels up to 3500 seconds Redwood.

Stress Relieving Large Welded Bridge Girders

Last week we published an account of the progress made in constructing the Runcorn-Widnes bridge, which is a steel arched bridge with a main span of 1082ft. It may be recalled that most of the site joints of the bridge steelwork are riveted, but shop welding was needed before delivery of the steel to the site. We have since received details of one aspect of this work, namely the method of stress relieving an important welded joint in certain of the girders.

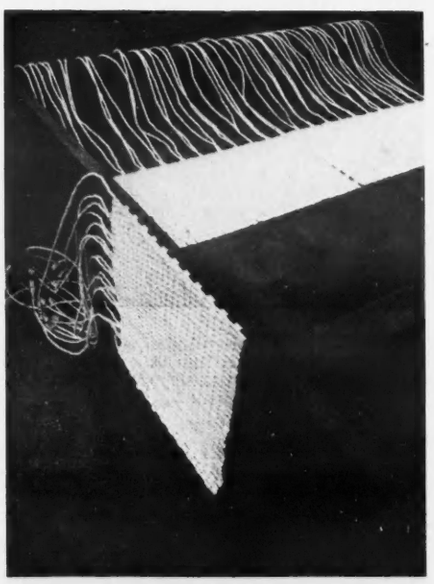
FOUR steel girders for the new Runcorn-Widnes road bridge have been fabricated at the Chepstow works of the Fairfield Shipbuilding and Engineering Company, Ltd. Each completed girder was approximately 80ft long by 6ft high and weighed in the region of 14 tons : they were welded, with $\frac{3}{4}$in thick webs and $1\frac{1}{2}$in thick flanges, and stiffened at regular intervals with 8in by $3\frac{1}{2}$in by $\frac{3}{8}$in angles. For convenience of manufacture each girder was fabricated in two separate 40ft lengths which were then joined by welding to produce the complete 80ft girder.

Strict specifications were laid down regarding the stress relief procedure for the weld joining the halves of the girders, as follows: (1) heat to 650 deg. Cent. at a speed not exceeding 150 deg. Cent. per hour, (2) soak for a period equal to one hour per inch of the thickest part of the heated area, (3) cool to 350 deg. Cent. at a rate not exceeding 100 deg. Cent. per hour and, finally, (4) allow to cool naturally to room temperature.

No conventional furnaces capable of accommodating such large girders were available at the Chepstow works. Electrothermal Engineering, Ltd., was therefore invited to undertake the stress relieving operation, using its " flexible furnaces," which are, in effect, mats composed of ceramic beads threaded on " hairpins " of nickel alloy resistance wire ; the latter are linked together to provide a series of electrical circuits capable of giving a maximum mat surface temperature of 1000 deg. Cent. Each circuit has flexible leads, and by bringing in or cutting out circuits. it is possible to control the mat temperature to close limits. The mats are very flexible, and in one direction can be bent to a minimum radius of 1in ; thus they may be wrapped around the edges of plate, &c. without difficulty.

Heat Input.—The flexible furnaces were capable of producing a maximum temperature of 1000 deg. Cent. and could dissipate 50W per square inch, but had to be considerably underrun in order to keep to the specifications. In fact, the density employed was well under 25W per square inch.

Power Supply.—Power for heating was



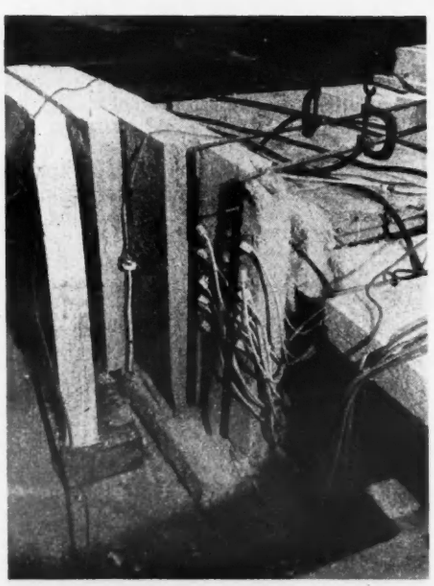
The " flexible furnace " mats in position on the upper face of the girder, prior to placing the lagging on this face

supplied by two standard 300A Quasi-Arc, and two English Electric 350A, welding transformers ; these are continuous rating current figures. By means of a standard earth clamp the end of each transformer lead was connected to a copper busbar, to which were attached leads from several mats. As the attachment was made by nuts and bolts it was an easy matter to disconnect or connect leads in order to lower or increase the temperature in any particular area as the need arose.

Thermal Insulation.—4in thick slabs of thermal insulation material was employed for lagging. Two types were used, the prime lagging (adjacent to the metal surface) being capable of efficient results at temperatures up to approximately 800 deg. Cent.; the outer or secondary lagging had an upper limiting temperature of about 500 deg. to 600 deg. Cent.

It was decided that a minimum distance of 3ft on each side of the weld should be lagged, and prime lagging was applied to the underside of the girder and to the inside of the flanges (on top of the mats and thermocouples), and secondary lagging then added. This was done with the girder in the vertical position, the lagging being held in position by boards and wire rope. The girder was then turned through 90 deg., and the upper surface lagged in a similar manner, the total thickness of lagging being in the region of 16in. Because of the efficiency of the crane drivers, it was possible to modify this procedure slightly for the third and fourth girders by lowering them directly on to the base lagging which remained on the shop floor when the first two girders were lifted after completion of stress relieving.

Temperature Recording.—The flexible furnaces were positioned, under the prime lagging, in the manner shown in the first illustration, and at strategic positions under the mats thermocouples were connected to type-800 ether temperature recorders. The thermocouples were calibrated by immersion in boiling water and the recorders checked to ensure that each gave a reading of exactly 100 deg. Cent. This was considered a sufficiently good check that they were all accurately matched. It was, of course, also essential to ensure that all the leads were exactly the same length, in this case 15ft.



A stage in lagging one of the webs. Note the busbars to which the leads from the mats are attached and, at the rear, a thermocouple to check the temperature inside the lagging

Stress relieving in progress : on the right are the two recorders to which were attached a total of twelve thermocouples

It should be noted that the thermocouples not only recorded the temperatures in the areas concerned, but were also used to monitor the mats, or sections of mats, and ascertain whether the temperature in any particular area under treatment should be increased or decreased.

In all seventeen thermocouples were positioned at various points around each girder, some in contact with the metal surface and others buried in the lagging.

Temperature Control.—Control of the heat input in order to comply with the specification cycle was achieved by varying the current output of each transformer, and at the switch-on stage the tappings were the lowest possible obtainable. The voltage and current readings were made in the conventional manner, using voltmeters and tong testers ; bearing in mind that welding sets by different manufacturers and of varying age have different drooping characteristics, all measurements were taken at the terminals of the flexible furnaces.

Any tendency for one area to heat more rapidly than another was corrected without difficulty merely by cutting out of circuit the appropriate mats or sections of mats, and thus it was comparatively easy to ensure uniform heating over the entire weld area.

The general rise in temperature during heating was maintained closely to specification requirements by stepping-up the output of the power sources to suit the readings shown on the recorders, at the same time adjusting any local difference in the manner just described. When the temperature in all areas reached approximately 575 deg. Cent., i.e. about 75 deg. below soaking temperature, the voltage and output current of the sets were reduced in order to avoid any chance of over-shooting the maximum temperature. It was found that interpretation of the curves shown on the recorders enabled the operators to predetermine very accurately the change of settings required.

Soaking was achieved comparatively easily, and the subsequent cooling-down stage amounted to little more than intelligent interpretation of the recordings. During the stage of cooling from 650 deg. to 350 deg. Cent. the furnaces were switched on and off as necessary to maintain a steady rate of cooling in each area ; this uniformity of cooling was made possible by the fact that each heater could be independently controlled. When the temperature had fallen to 350 deg. Cent. all heaters were switched off and the entire assembly allowed to cool naturally, without disturbing the lagging.

After the cycle had been in operation for some time, heat rising from the lower portion of the vertical flanges increased the rate of heating of the upper portion. For this reason it was essential to be able to control the heating of these upper surfaces by putting the appropriate mats out of circuit until the temperature was uniform throughout the entire flange. This was done simply by splitting the busbars for the flange heater into halves connected by an earth clamp, as mentioned earlier.

Control of temperature was undoubtedly influenced by the careful attention paid to the lagging. Heat losses were minimised, and, temperature gradients through the girders were comparatively small, and a good deal of the success of the heat-treatment of these girders was attributed to the care given to the thermal insulation.

At the commencement of the cycle the rate of temperature increase was slower than that called for by the specification. The slowness of heat input resulting from passing only a very small current through the mats provided a fair amount of time for the thermal inertia of the flexible furnace, the lagging and girder to be overcome, and reduced to an absolute minimum the possibility of major temperature gradients from one face of the girder to another, or from one side of the flanges to the other. After running the heaters up to about 200 deg. Cent., the rate of temperature rise became rather more rapid, but still within specification limits. Up to 650 deg. Cent., by and large, all the curves were well within the specified 150 deg. Cent. per hour, deviations not exceeding $\pm$50 deg. Cent.

The principal firms concerned in the design and construction of the Runcorn-Widnes bridge were named in our article last week.

Mechanised Assembly of Television Receivers

A two-to-one increase in output potential of G.E.C. television receivers has been achieved by mechanised processes of assembly taking advantage of the extent to which circuitry is now embodied in small and light printed panel units.

PRODUCTION of television receivers at the Coventry factory of The General Electric Company, Ltd., is at the rate of 5000 a week. The figure reflects the successful application of a mechanisation policy which balances what is technically possible with what is economic and in the interests of the customer. During an inspection of the plant on July 19 visitors were reminded of the importance of preserving adaptability in order that improved circuitry and components can be embodied readily in the receivers by simple modifications. It is claimed that the assembly processes at Coventry are the most highly mechanised in the world, and the interest they have created is made evident by special visits from representatives of United States manufacturers to see the plant in operation.

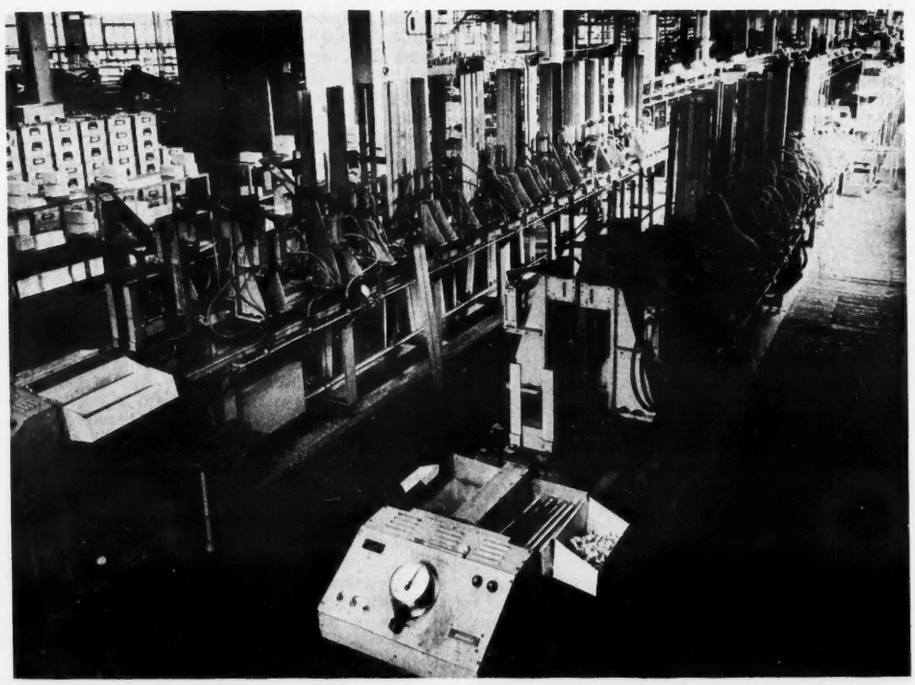


Fig. 1—Machines for mechanical assembly of i.f. and timebase circuit components on printed circuit panels

Two printed circuit boards carry respectively the timebase and i.f. circuits of the receiver, and the automatic insertion of components in these boards is the first stage of the mechanised procedures. The two insertion machines for the i.f. and timebase components are seen in Fig. 1, and Fig. 2 shows an insertion head with the lower part of one of the magazines into which the parts are loaded, about 250 at a time. Twelve components are held in stock in the head at all times, and since a board halts at each station for twenty-five seconds the operator has three minutes in which to replace a magazine when necessary. From one to four components are inserted at a time by shearing the wires to the correct length, threading them through the holes in the board, and bending the ends over on to the copper surface. Valve holders are supplied ready-loaded in tubular magazines. Hand assembly is used only for certain larger components such as transformers.

It is stated that one of the biggest contributors to time-saving in production has been the mechanical soldering machine. A chain conveyor picks up each board presented to it and moves it through the fluxing and soldering stages. Flux is automatically sprayed on the copper surface, followed by infra-red heating and drying. The panel is then allowed to float on a solder bath for a few seconds, after which it is shaken to dislodge any surplus. There is then a careful inspection of the soldering, valves are fitted, and the panels pass to the testing machines.

Boards are seen passing through the various stations of a testing machine in Fig. 3. The machine warms up the valves prior to testing to allow the performance to stabilise and automatically positions panels at various stations. Boards are inserted into a series of identical trollies and connections at each station are made by spring-loaded plungers and plugs and sockets. The trollies are indexed into the test positions by air cylinders and automatic lifts are arranged at each end of the machine so that the trollies circulate. Meters, cathode-ray tubes and frequency indicators are at eye level behind the trollies with the operator controls near at hand, so that no reaching across the test panel is required.

A card is attached to each trolley, and passes through a punching head at each station. If there is a fault, a push button is operated to punch a hole in the card. At the end of the testing machine clear cards show " good " panels while panels requiring attention have cards showing the exact location of the fault.

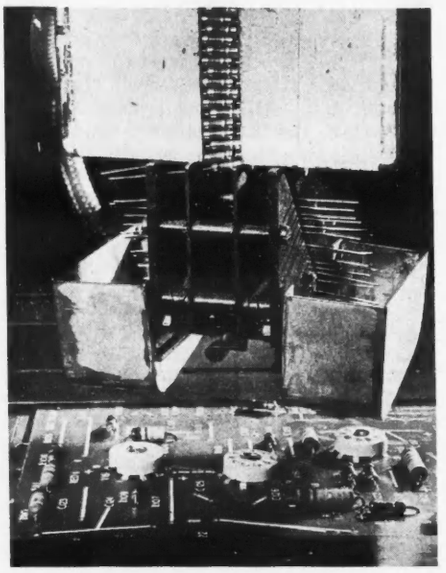


Fig. 2—Delivery head of mechanical assembly machine showing magazine of components

The main production lines begin with the metal chassis framework and finish with the receiver in its carton. Assembly operations are carried out on long indexing tracks which position the chassis in front of each operator in turn. Accurate location of the cathode-ray tubes is essential for the chassis to fit correctly into the cabinet ; a jig worked by compressed air is used to ensure this. Manufactured items including printed circuit boards, turrets, deflector coils and cable forms are fed to the appropriate positions on colour-coded trays by several overhead conveyors. Tubes are enclosed in colour-coded protective coverings and loaded direct from the reception point at ground level on to a conveyor which carries them up through the building to the assembly floor, where they circulate continuously past the operators. After the inspection and testing

Fig. 3—Automatic testing machine for assembled printed circuit panels

stages the chassis are fitted into cabinets which are supplied complete with protective glass from another overhead conveyor. Automatic lifts take sets which need rectification to a parallel line, whence they are returned to the first available space in the main flow.

Final test and clearance are followed by packaging, the cartons being prepared on an overhead gantry, dropped over the receiver, and inverted for sealing. A stapling machine adjusts automatically to fit various carton sizes for different models and staples the package top and bottom in one operation. An automatic lift is being installed to convey television sets and radio receivers from the assembly floors to ground level for van loading.

All indexing operations requiring timing and co-ordination are controlled from a central console with master electronic timing circuits and individual process timers. The master circuits provide for starting up and shutting down the plant at various periods during the day and at week-ends.

The printed circuits are produced at the factory from copper-clad plastic (phenolic) board by a photographic etching process. At the outset they are guillotined to size and pierced with two holes which serve to locate them accurately throughout the later assembly processes. Printing takes place in machines holding four negatives at a time. All negatives are examined daily and replaced if necessary. A bauxite vapour blast is now being used for closing the pores of the metal and preventing oxidation. Boards are varnished selectively in preparation for dip soldering, so that solder will adhere only where required, and are printed on the reverse side with component circuit references by the silk screen process as an aid to servicing.

The printed circuit process is already being used at Coventry for the production of certain radio receiver coils and is to be introduced shortly for the coils in the turret tuners of television receivers. The coil turns are etched in one plane on the board and tuning is effected by varying the gap between the coil surface and an adjustable core mounted above it.

For testing receiver performance duplicate sets of picture and pulse signal generating equipment are installed (Fig. 4). Receivers are also selected at random for life tests in which they are subjected to the equivalent of four years' use in twelve months—6600 hours' working and 2200 on-off switchings. Others operate for 540 hours in a month. A mechanical test seen in progress during the visit was subjecting a cartoned receiver to low-frequency, high-amplitude vibration with a frequency of 3 c/s and an amplitude of $\frac{3}{8}$in. Line timebase coils were shown undergoing tests for continuity, impedance and corona discharge under e.h.t. Test apparatus designed and built in the works is an essential element in the comprehensive system of checking and quality control which has been evolved as a complement to the speeding up of production by mechanical devices.

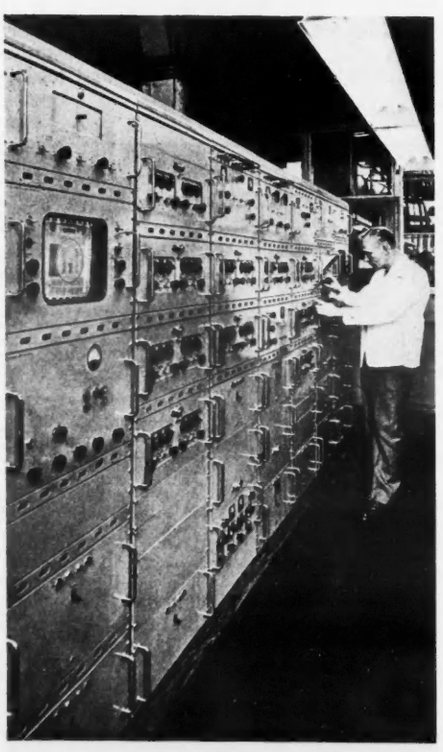


Fig. 4—Picture and pulse signal generating equipment for receiver tests

Electronics in Medicine

THE Third International Electronics Conference, organised by the Electronics and Communications Section of the Institution of Electrical Engineers in association with the International Federation for Medical Electronics, was held at Olympia, London, from July 21 to 27. It was opened on July 21 by Sir Willis Jackson, President of the Institution. At the first general session on the following day, Dr. D. K. Zworykin gave a general outline of promising developments in a lecture on "Prospects in Medical Electronics." Perhaps the most evident trend in electronics, he said, was towards miniaturisation both in dimensions and power requirements. The biggest step in this direction without question had been the development of solid-state devices exemplified by the transistor. Further fruits of this development were the crystal diode, the thermistor, the crystal photoelement, the miniature magnetic core and the transfluxor, and, more recently, the tunnel diode.

For medicine this meant, first that one could foresee the introduction into the various organs of electronic probes so small that they did not interfere materially with the functioning of the organ in question and yet could transmit significant information regarding its operation. Illustrations from current practice were the introduction of pressure transducers and other measurement instruments into the heart through a catheter introduced through a vein, and the various pills or endoradiosondes which had been constructed for examining the gastro-intestinal tract. In the second instance, pressure, temperature and acidity all seemed to be capable of measurement without too great difficulty. The use of circuits deriving their energy by induction from external sources should remove the time limit for their activity, which, in radio pills in present use was set at seventy-two hours by the energy stored in the battery. Another development which might be anticipated was the insertion of active electronic elements to replace or supplement the action of organs which had become defective—the use of surgically inserted heart stimulators for patients whose heart action required continuous or repeated stimulation was an example of this. While, at the present time, the stimulator was coupled electromagnetically to a pulse generator stationed in the hospital, miniaturisation of the equipment should make it readily possible to make the entire equipment portable, so that the patient would regain his freedom of movement. The replacement of such organs as the kidneys, heart or lungs by surgically inserted prosthetic devices with electronic controls might seem remote at the present time, but there was every reason to believe that eventually it would be realised.

One could also foresee important effects of miniaturisation in hospital practice. Individual paging systems for physicians might well be supplemented by devices telemetering data such as temperature and pulse from the individual patient to a central recording point. Miniaturisation entered here both in the construction of the sensing probes, such as a thermistor thermometer, and in the design of a transmitter.

One of the most important effects of miniaturisation in electronics on medicine might be indirect. Thus, the enormous data-handling capacity which was required for an efficient public health service was attainable only with the aid of units which were small in dimension and had low power consumption. With central stations storing the health records of the entire population in rapid-access electronic memories, it would become possible to mail out in a continuous stream health questionnaires which could be completed and returned by the individual recipient. The machine, in recording the reply, would compare it with the data received from the same individual on previous occasions, and if the comparison indicated the development of a pathological condition would send out a notice asking that the person in question seek medical help. The physician consulted, in turn, would have the benefit of the standardised health record stored at the central station in helping him to diagnose the condition of his patient. Such a relatively simple system would form an important element in preventive medicine.

The same data-handling systems which could store the health records of the population might be used to construct a giant *Index Medicus* which would help the physician in determining the pathological cause of any set of symptoms presented by a patient and prescribing a cure for it. In effect, it would be a record of past experience concerning the correlations between symptoms, diseases and therapy. Small tentative beginnings towards computer diagnosis had been made in very restricted fields of pathology, such as the hematologic and ophthalmic diseases. They had indicated the feasibility and the enormous magnitude of the project. At the same time, the need for it became ever more obvious as the extent of medical knowledge exceeded more and more the grasp of any human brain.

In summary, it was clear that electronics would have a radical effect in changing the practice of medicine in the future. This effect would not be to replace the human relationship between patient and physician by a reliance on automatic devices. Rather, it would make possible adequate medical care by adding, to the care of the physician, services which could be provided by modern technology and giving the physician added facilities for dealing with the problems which confronted him.

Exhibition of Equipment

A medical electronics exhibition was held concurrently with the conference. Among the firms exhibiting, the Radio and Electronic Components Division of Associated Electrical Industries, Ltd., showed production models of the Siemens Ediswan "Neopulse," a fingertip, transistorised electronic pulsemeter for operating theatre use. The "Neopulse" permits the blood pressure of a patient to be measured without resort to a stethoscope, or allows a patient's pulse to be continiously monitored during an operation. It relies on a microphone secured to the patient's fingertip by an elasticised strap to pick up the pulse, which is then fed via an amplifier to an output meter. There is sufficient pulse indication in the fingertip to produce corresponding "kicks" on the output meter. The "Neopulse' also incorporates a pressure manometer, so that, if an occluding arm cuff is employed as in the stethoscope method and is pressurised until the output meter fails to indicate the pulse, the patient's blood pressure can be read off on the manometer. The "Neopulse"

is battery-operated and therefore completely self-contained. It measures approximately 7¼in by 4½in by 2¼in and weighs approximately 3½ lb. Another section of A.E.I., the Heating and Welding Department of the Transformer Division, showed an infra-red syringe steriliser which can deal with approximately 360 medium-size syringes or 600 small syringes an hour. Operation is automatic, the syringes passing under the infra-red elements on a conveyor belt. With this unit syringes can be sterilised after they have been assembled and sealed inside containers, and on emerging from the steriliser they can be stored at once for future use without further handling. Items shown by the group in model or display form included cobalt therapy equipment, the respiratory mass spectrometer (described in our October 23,1959, issue) the " EM6 " electron microscope and an eye magnet for the removal of ferromagnetic bodies from the eye.

Several X-ray image amplifier installations similar to the prototype described in our May 29 issue this year are now working, and the equipment was shown at the exhibition by Marconi Instruments, Ltd. The single-stage, high-gain image intensifier tube used in this instrument was shown on the stand of the English Electric Valve Company, Ltd., whose exhibit also included a prototype storage device, selecting and storing a single frame of a television form of picture. The storage time of the display can be several hours, but the picture may be erased instantaneously at will. This device could be of use in teaching hospitals where a particular phase of a major operation could be " frozen " on the monitor, for further explanation or discussion by an instructor, whilst the operation continued. Radiologists would be able to retain an X-ray picture displayed by an image intensifier for immediate evaluation and diagnosis, without necessity of prolonged dosage or awaiting the results by normal photographic means. Another advantage is that the image stored can be greatly magnified, thus permitting an easier diagnosis.

Oil Service Headquarters at Feltham

ON Thursday of last week Mr. H. C. Tett, the chairman and managing director of Esso Petroleum Company, Ltd., formally opened the new headquarters of the Technical Sales Department of the company at Faggs Road, Feltham. The building, of which we reproduce a photograph, marks another stage in the development of this department and its increasingly important role in maintaining and improving the quality of Esso products. This department has no responsibility for production or sales but its work is concerned with the technical aspects of marketing and so is available to provide technical service to the marketing department and to the users. The value of such work was realised some thirty years ago when a laboratory was opened at Battersea with a staff of three. Later a move was made to Vauxhall and by 1930 the staff had increased to thirty ; however, the increasing consumption of petroleum products coupled with the greater complexity and variety of industrial applications has so expanded the work of the department that it was essential to provide more facilities for the solution of problems posed by industry and to house a staff now numbering about 120. An existing building, adequate for the purpose, was acquired at Feltham; the interior has been remodelled to satisfy the requirements of the department and an engine test house has been added.

The staff is broadly divided into two closely inter-related and complementary groups, those who are engaged in laboratory work and those who maintain liaison with industry. Besides finding the answer to customers' problems and ensuring the continuance of product quality the department has also to assess trends in terms of future requirements so that advance planning can be put in hand to evolve and test new and better products able to satisfy the requirements of new equipment. Anticipation of such requirements necessitates close contact with industry and such contacts cover all industries where petroleum products are used. Representatives besides taking note of possible future developments are also concerned with present applications and are available to offer specialised experience to assist local representatives to resolve complaints and to advise customers on the use of oil products in new and existing equipment. These activities relate to the aviation, automotive, power generation, shipbuilding and marine engineering industries and to agriculture, and range from nuclear power stations to domestic boilers and from the aircraft engine to the small two-stroke unit.

There are two sets of laboratories at Feltham, the mechanical and the chemical groups, both of which are subdivided and in which no long term research nor routine testing is carried out. In the first named group are an engine laboratory mechanical test rigs, a boiler laboratory, a maintenance workshop and the boiler-house.

The boilers in the boiler-house provide facilities for testing and assessing working performance standards of oil-burning equipment, for testing various grades of fuels and for the employment of instrumentation for that purpose. In the engine laboratory there are a number of soundproofed cells, arranged along a central corridor, seen in our illustration, in which engines are mounted to establish the performance number of aviation fuel, the octane number of gasolines, using C.F.R. methods, and the octane rating of diesel fuels. Single-cylinder " Caterpillar " engines are used for testing heavy-duty lubricants, while Petter engines are employed for development work on lubricants. Mechanical rigs are employed for the testing of greases, extreme pressure lubricants and the effect of lubricants on valve train wear. One test noted was a bearing test in which the bearing carried a steady load of 1 ton for 1,000,000 revolutions. There are testing facilities of domestic oil-fired boilers in the boiler laboratory, and here development work is carried out on boilers, burners and fuels largely in conjunction with the manufacturers, some tests lasting for 1000 hours and longer.

Fuels, lubricants and special sections form the main divisions of the chemical laboratories where essential analysis and testing are carried out. All categories and grades of fuels are tested and the calorific value, sulphur content are established and the vapour pressure measured, for the purposes of easy starting and the avoidance of vapour lock, in an apparatus developed by the company to supplement the Reid test. Flame temperatures and radiation characteristics of aviation turbine fuels are measured, in terms of Luminometer numbers, and also their stability. For the latter a fuel coker is used to assess the

Headquarters building housing the three main laboratories of the Technical Sales Department

Central corridor of engine laboratory showing engine cells

extent to which the fuels may form deposits under conditions of high temperature. In this equipment the fuel is passed at a fixed rate through the annular space between two tubes, the inner tube containing a heating element which raises the oil to 300 deg. Fah. At 400 deg. Fah. the fuel is passed through a sintered stainless steel filter, having a pore size of 60 microns, and the flow continued for five hours or until deposits in the filter set up a pressure differential of 25in Hg. The condition of the surface of the preheater tube is also visually compared with a set of standards and taken into consideration.

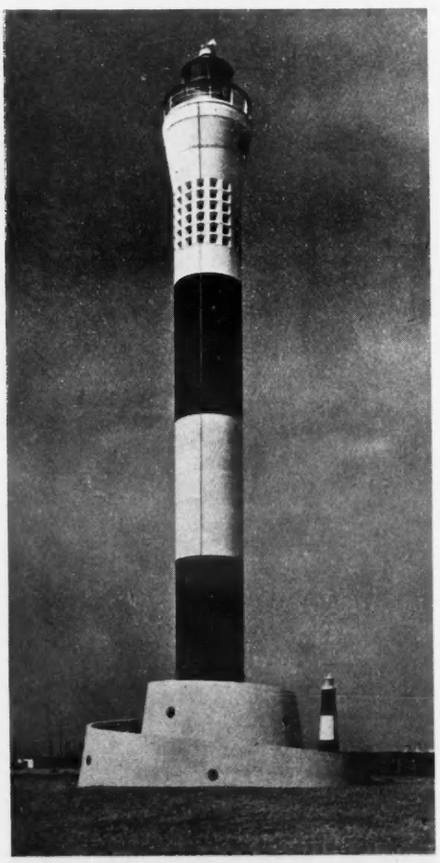
Lubricating oils, greases, waxes and bitumen are examined in the lubricants section and tests establish the resistance of grease to shear, in anti-friction bearings ; and to penetration and its stability. Other tests are concerned with the steam contamination of turbine lubricating oils and there is a wheel tracking test for bitumen. For the detection of metallic elements in boiler deposits, sludges and fuel ash there is a flame photometer which is capable of recording 0·01 p.p.m. and of determining fifteen elements. The equipment also includes a direct-reading emission spectrograph which can be used for detecting and determining any metal, and some non-metals, at concentrations as low as a few parts per million, and recording the result within a few minutes. The instrument has two direct-reading heads and can detect twenty-two elements, and is used for dealing with additives and contamination of lubricants. Much of the work carried out by this instrument is concerned with used lubricants from British Railways diesel locomotives to establish the presence of metallic particles resulting from wear. Work in the special laboratory deals with questions related to the electrical properties of cable oils, the breaking point of bitumen products, the emulsion stability of soluble cutting oils and the corrosion of cast iron by such oils and rust preventives.

Setting-up the cobalt-60 source holder for radiography of the concrete walls of Dungeness lighthouse tower

Dungeness Lighthouse

THE new lighthouse at Dungeness, Kent, is the first major lighthouse to be built for Trinity House for over fifty years and some interesting innovations are to be seen in its design. They include the use of a stationary, flashing Xenon lamp instead of the usual revolving navigation light, and the use of precast post-tensioned concrete rings in the structure of the lighthouse tower.

The slenderness of the 130ft high tower (illustrated here) is attributable to this method of construction in which the shell of the tower is built up of twenty-one precast rings which are post-tensioned by vertical wires. Each ring is 5ft high, 12ft diameter and has a wall thickness of only 6in. The rings were made at the Rye works of Spun Concrete, Ltd., and were transported by low loader vehicles to the site, where they were placed in position, one on top of another, by a Coles " Conqueror " crane with a 142ft jib and a lifting capacity of 11¼ tons.



The new Trinity House lighthouse at Dungeness. The 130ft tower is built up of post-tensioned precast concrete rings and has an overall diameter of 12ft, flared to 16ft at the platform

High-tensile steel wires were run through vertical tubes in the walls from top to bottom of the tower and tension was applied by jacks. These tubes containing the stressed cable were grouted under pressure, the effectiveness of the grouting, both at the anchorages and in the tubes, being confirmed by radiographic tests.

Radiographic examination of the 6in thick concrete walls of the tower was carried out by Pantak, Ltd., Windsor, Berks., using a cobalt-60 bomb which has a strength of 7.5 curies. This source was contained in a holder specially designed for safety in operation, transit and site storage. The container consists of a mild steel case with dished ends, the case being filled with 500 lb of lead and an 80 lb hollow tungsten core, which has better shielding properties than lead. A double locking device is incorporated to ensure that the isotope is either locked in or locked out before the handling rod can be removed, the source being handled by this unit by remote control. The surface radiation intensity of the source holder was only 20 milliröntgens per hour, and at that level it was considered sufficiently safe for the source to be kept in a secure place on the site, although care was taken to ensure that no one had access to within 3ft of the place in which it was stored. The radiographic work was done during the hours of darkness and occupied three nights. On this 6in thickness of wall, the exposure time using the cobalt-60 source was seventy minutes using a Kodak " D " film, the films being placed in a complete ring on the outside of the tower wall and one simultaneous exposure made. The source (illustrated here) was centred in the shaft by block and tackle and located opposite each set of anchorages, there being four rings or anchorages at 30ft intervals. In addition to the anchorages, an exposure was also made to check the grouting in the intervening tubes. Any grouting flaws which were identified in the anchorages and tubes were rectified by subsequent drilling and regrouting.

The lighthouse tower was built for Trinity House by Taylor Woodrow Construction, Ltd., and the architects and engineers were Ronald Ward and Partners. The radiographic procedure was evolved by the Cement and Concrete Association in conjunction with Pantak, Ltd.

From the accompanying view of the lighthouse it will be seen that the tower rises from a white concrete base in the form of a spiral ramp. This ramp encloses a machine room which contains all the electrical controls, generators and fog-signal equipment. In the top white band of the tower there are six rows of apertures for the sixty Tannoy loudspeaker units associated with the fog signal which is actuated automatically by a fog detector invented by Trinity House research staff and manufactured by Stone-Chance, Ltd., under licence from the National Research Development Corporation.

The banded appearance of the lighthouse tower was achieved by specifying separate black and white concrete mixes which were determined as a result of preliminary tests by Terresearch, Ltd. Above the fog signal apertures the tower swells to a diameter of 16ft at the platform surrounding the lamphouse.

The new tower will be equipped with main and subsidiary lights and associated equipment. The main lighting apparatus comprises duplicated lens systems mounted one above the other within a standard lantern. Each lens consists of 360 deg. annular glass segments, precision moulded and mounted around a vertical axis within a helical framework of gunmetal which is finished matt black. In this way light from the very small light source is not obscured in any horizontal direction. The focus of the lens system is 250mm and this refracts the rays of light from the lamp into the horizontal over an angle of 300 deg., the remaining 60 deg. being provided with a screen.

Each lens will have a Xenon lamp at its focus—the one lamp and lens combination acting as a standby to the other—changeover being effected automatically upon failure of the working lamp.

The lamp illustrated is a " Mazda " 2kW

High-pressure Xenon discharge lamp of the type that will be installed in the new Dungeness lighthouse. Flashed on for 1·3 seconds every ten seconds it will consume about 300W

high-pressure Xenon discharge lamp of a type that was developed by the A.E.I. Lamp and Lighting Company, Ltd., for use with B.T.H. cinema projectors. This lamp is slightly more than 12in long and weighs just under 2 lb. With an operating cycle consisting of a 1·3-second flash every ten seconds the lamp and its control gear will consume only about 300W, compared with about 1kW in the case of a tungsten filament lamp for the same light output with the aid of a revolving lens. The flashing Xenon lamp does not require a revolving lens.

The lantern has circular glazing 8ft 4½in internal diameter—the panes being set between helical gunmetal frames. The lower cylindrical murette and conical roof are of galvanised steel—the usual ventilators and access door being provided.

The subsidiary light consists of a lens identical with one of the above lenses in section and focus but comprising two 45 deg. segments which project two beams of light through two windows lower in the tower. The beams provide colour sectors necessary for vessels rounding the Ness. Both segments subtend a common 250W light-source and focusing telescopes provide accurate means of checking lamp focus. The above lighting apparatus and lantern (excluding the lamps) were supplied by Stone-Chance, Ltd.

The new light, which is the subject of continuing experiment, is expected to have an output of 750,000 to 1,000,000 candle power and it is hoped that the combined effects of circuit modifications and improvements in lamp and lens design may be to produce about 5,000,000 candle power. The main gains to be expected from the Xenon lamp are reductions in physical size and power requirements and the use of a fixed lens instead of a revolving lens.

Motor Vehicle Testing

REGULATIONS laid before Parliament last week provide for official testing of road vehicles from September 12, 1960. At a later date, it may become unlawful for a vehicle registered more than ten years earlier " to be on the road " without a valid certificate of compliance with certain statutory requirements. These requirements are laid down in the Motor Vehicles (Tests) Regulations, 1960 (S.I.1960/1083), H.M. Stationery Office, price 1s. 6d. A manual of guidance for vehicle examiners, price 2s. is not yet available. A general guide to the regulations is printed below.

Vehicles Covered by Regulations.—The Motor Vehicles (Tests) Regulations, 1960, have been made by the Minister of Transport under Section 65 of the Road Traffic Acts, 1960 (which was enacted recently to consolidate the Road Traffic Acts, 1930 to 1956), and were laid before Parliament on July 18, 1960. They apply to all motor vehicles which are defined in the Road Traffic Act, 1960, as heavy motor-cars, motor-cars and motor-bicycles, except track laying vehicles, goods vehicles which exceed 30 cwt unladen weight, public service vehicles adapted to carry eight or more passengers, articulated vehicles or parts of articulated vehicles, works trucks, and pedestrian-controlled vehicles. They will apply, therefore, to motor-bicycles, three-wheelers, smaller goods vehicles, passenger vehicles including private cars, taxis, small public service vehicles with less than eight passenger seats, buses or coaches which are licensed as " Private," dual-purpose vehicles up to 2 tons unladen weight.

Brakes.—Every vehicle eligible for a test except a motor-bicycle must have a parking brake. Every vehicle must be equipped with an efficient braking system having two means of operation or two efficient braking systems each having a separate means of operation, except veteran motor-cars registered before January 1, 1915, and veteran motor-bicycles first registered before January 1, 1927, which need have only one efficient braking system. These braking systems must comply with certain requirements as to their efficiency.

There will be a general inspection of each braking system and its means of operation to see whether there is evidence of faults which would mean that it was not working efficiently. The items to be examined will be found in the Third Schedule to the Test Regulations and cover such matters as the condition of brake rods and cables which must not be rubbing or chafing, the examination of hydraulic systems for leaks or chafing and freedom from air, the condition of hand brake pawls and ratchets, reserve travel of foot pedals and hand levers, evidence of oil leakage in brake drums or hubs, uneven braking between one wheel and another, and any other evident defect which would mean that the prescribed requirements relating to brakes were not being met.

A test of braking efficiency will be carried out either on a suitable apparatus in a garage—e.g. a static brake-testing machine for cars or a spring balance or inclined slope for motor-bicycles—or with a decelerometer on a road. Road tests will be carried out where necessary at moderate speeds on suitable roads with due regard to the convenience of residents. Normally the vehicle will be driven by the authorised examiner, but exceptions may be made, e.g. for veteran cars.

In order to ensure that common standards of braking efficiency are applied at all testing stations, the Minister of Transport has recently issued the Motor Vehicles (Construction and Use) (Amendment) Regulations, 1960 (S.I.1960/1065), which will come into effect on September 1, 1960. These Regulations prescribe minimum standards of efficiency which must be achieved by the braking systems of those vehicles which are eligible for test. This braking efficiency is established by finding out the maximum braking force (in pounds) developed by the brake during the test and expressing this as a percentage of the total weight of the vehicle, including any passengers or load which are being carried at the time (the owner of the vehicle may present his vehicle for test in any safe condition of load). Some of the methods of test will establish this percentage automatically but others will require the actual braking force and weight of the vehicle or load to be known. The authorised examiner will suit the method of test to the particular vehicle being tested.

The standards to be achieved by the brakes of vehicles which are eligible for test are set out below.

Vehicles with Four or More Wheels Other than Veteran Cars

(*a*) with either or both brakes operating on four or more wheels :	
A four-wheeled brake (This will usually be the footbrake)	50 per cent
and a second brake (This will usually be the handbrake)	25 per cent
(*b*) with both brakes operating on less than four wheels :	
One brake (This will usually be the footbrake)	30 per cent
and a second brake (This will usually be the handbrake)	25 per cent

Three-Wheeled Vehicles Other than Veteran Cars

(*a*) With either or both brakes operating on three wheels :	
A three-wheeled brake (This will usually be the footbrake)	40 per cent
and a second brake (This will usually be the handbrake)	25 per cent
(*b*) With both brakes operating on less than three wheels :	
One brake (This will usually be the footbrake)	30 per cent
and a second brake (This will usually be the handbrake)	25 per cent

Veteran Motor-cars Registered before January 1, 1915

Four-wheeled vehicles :	
Either one four-wheeled brake	50 per cent
Or one brake operating on less than four wheels	30 per cent
Three-wheeled vehicles :	
Either one three-wheeled brake	40 per cent
Or one brake operating on less than three wheels	30 per cent

Motor-Bicycle, With or Without Sidecar, Other than Veteran Motor-Bicycles

One brake (This will usually be the front brake)	30 per cent
And a second brake (This will usually be the rear brake)	25 per cent

Veteran Motor-Bicycles

One brake	30 per cent

Steering.—The steering gear must be maintained in good and efficient working order and be properly adjusted. The tester will examine (see Third Schedule to the Tests Regulations) the condition of track rods, steering arms and drag-link joints and inspect king pins for excessive stiffness or wear and see whether securing nuts and split pins are in position. He will see whether the steering box is securely attached and if front wheel hub bearings are properly adjusted. He will look for excessive movement at the steering wheel. The front forks and handlebars of motor-bicycles must be firm and have no excessive play and the wheel bearings be free from excessive slackness. If a side-car is fitted, the wheels must be properly aligned. The examiner may also take account of any other evident defect which would mean that the prescribed requirements relating to steering gear were not being complied with.

Lighting.—Briefly, the lighting requirements demand that each vehicle tested is fitted with all obligatory lamps (i.e. side and rear lamps) and reflectors at front and rear (the test is not concerned with the lamps illuminating number plates, stop lamps or direction indicators). In addition, headlamps must not cause dazzle.

The test of obligatory lamps and reflectors will establish that the vehicle is equipped with the correct number of such lamps and reflectors and that they are in the right position, that they are clean, unobscured and efficient and can be used to show a light to the front or rear visible from a reasonable distance.

The beam from headlamps must be permanently deflected or be capabe of being deflected by the driver so as not to dazzle any person on the same horizontal plane as the vehicle at a greater distance than 25ft from the lamp, whose eye level is not less than 3ft 6in above the ground (see Regulation 9 of the Road Vehicles Lighting Regulations, 1959). The Tests Regulations (Third Schedule) provide for the manner in which this test will be carried out using a suitable apparatus measuring the direction and deflection of the beams.

If a vehicle is not fitted with any front or rear lamps or if they have been permanently blacked out or the vehicle has no system of wiring at all for connecting the lamps to the source of electricity, the vehicle is not subject to the test of lighting at all because it could not be used on a road in that condition at night. A vehicle will not, however, be treated as exempt from the test of lighting equipment merely because the bulbs or fuses have been removed or the wiring has been disconnected.

Test Certificate.—When the test has been carried out the examiner will issue a test certificate if the vehicle complies in all respects with the statutory requirements. If the vehicle does not so comply he will issue a notification of refusal of a test certificate which will indicate briefly the aspects of the test in which the vehicle has failed. In certain circumstances the examiner can refuse to carry out a test, viz :

(*a*) If evidence of first registration is required for the purpose of the test and the owner does not produce this evidence.

(*b*) If the vehicle is so dirty that it would be unreasonably difficult to carry out the test.

(*c*) If a driving test is necessary to complete the test and the vehicle is not provided with sufficient fuel and oil for this purpose.

(*d*) If a driving test is necessary and the vehicle is not licensed.

(*e*) If the vehicle is loaded and the load is not properly secured as required by the tester.

In particular, an examiner need not carry out a brake test if carrying out the test would be likely to cause danger to any person or to the vehicle or any other property because of the condition of the vehicle. In such circumstances a notification of refusal will specify that a test of the braking system could not be safely carried out.

Appeals.—An appeal against the refusal of test certificates by an examiner can be made to the Minister. Notice of appeal must be given on a special form obtainable from any Traffic Area Office of the Ministry of Transport and should be sent to the nearest Traffic Area Office, the address of which can be obtained from the examiner, within fourteen days of the date of the notification of refusal of a certificate. Examination of the vehicle will be carried out by a Ministry inspector normally at the testing station where the vehicle was previously rejected.

SHORTER REPORTS

Royal Society's Tercentenary Exhibition

AN exhibition of outstanding achievements of British science during the last ten years was the focal point of a conversazione held at Burlington House, London, on July 23, during the celebrations marking the tercentenary of the Royal Society. This exhibition has been open to the Society's guests during the week, and is open to the public to-day, Friday.

Although the exhibition illustrates scientific progress during the last decade, many of the exhibits and the work to which they relate have very much earlier origins. Thus the display devoted to calculating machines, in the entrance hall, acknowledges the pioneer part played by Charles Babbage, in 1823, who made the first practical proposal for a large-scale mechanical computer and who first conceived the idea of endowing such a machine with the power to comply with consequential instructions. Unfortunately Babbage's concept was more than a century ahead of its time : with the mechanical components then available the machine that he envisaged would have been far too bulky to be practicable. It is interesting to speculate what Babbage might have been able to do if miniature electronic components, transistors, ferrites and printed circuits had been at his disposal ! To-day, in the computer exhibits at Burlington House the emphasis is partly, for reasons of space, on the components and assemblies that are built up to make modern computers. Among the components that may be used in the not-too-distant future are thin films having the electrical characteristic of superconductivity, whereby calculating speeds of the order of 20,000,000 operations per second are feasible. Such devices are being developed, *inter alia*, at the National Physical Laboratory, the Royal Radar Establishment, Malvern, and the Services Electronics Research Laboratory, Baldock. One of the exhibits at Burlington House shows that similar operating speeds are being achieved with thin magnetic films at the Royal Radar Establishment : British firms engaged in computer manufacture are also working on parallel lines. Universities, too, have made, and are making, major contributions to the development of computers. Birkbeck College, London, the department of electrical engineering, University of Manchester, and the mathematical laboratory, University of Cambridge are participating in these exhibits devoted to calculating machines.

A group of exhibits in the Diploma Galleries relates to exploration by radio and illustrates British work on radio-astronomy and on the ionosphere. There are representations of several recent experiments at the Jodrell Bank Experimental Station, near Manchester. These experiments include satellite observations, radio continuum surveys, radio echo studies of the moon and meteors, a new accurate measurement of the astronomical unit, diameter measurements of 300 radio sources and a search for a galactic magnetic field. The display includes a model of the 250ft radio telescope at Jodrell Bank.

The second major exhibit in this group is that of the Mullard Radioastronomy Observatory (Cavendish Laboratory, University of Cambridge) which is mainly concerned with studies of radio stars, galactic structure and the outer corona of the sun. Of the recent discoveries made from this observatory, the most spectacular is that of the existence of a nebula which is nearly 5000 million light years away from the earth and is receding from it at about half the velocity of light. As a result of these observations it was possible to orientate the Mount Palomar optical telescope to take photographs of the newly discovered nebula, designated 3C295.

The Cambridge radio-star interferometer used for work of this kind consists of two aerials working in conjunction : one (east-west) is 1450ft long and the other (east-west) is 190ft long and is mounted on rail tracks running 1000ft north-south, both aerials being paraboloids 65ft wide. By moving the smaller aerial to take observations from successive positions along the rail tracks it is possible to " synthesise " a system which is equivalent in resolving power to two paraboloids each 750ft in diameter. The final resolution is 20 minutes arc in right ascension and 30 minutes arc in declination. By this system of " aperture synthesis " the aperture of the radio telescopes is built up by the combination of observations taken on successive days. All the observed data are recorded on punched tape and are then combined in the Cambridge University " Edsac " computer to provide a map of the relevant part of the sky.

A model using ultrasonic waves illustrates a method which has been used to measure horizontal drifts in the ionosphere and typical results are displayed, to illustrate some of the work done at the Radio Research Station, Slough, the University College of Wales, Aberystwyth, and the Cavendish Laboratory, Cambridge.

Another exhibit in the Diploma Galleries is one concerned with metals. It is shown for example how the Haas-van Alphen effect (the oscillatory variation of magnetic moment with magnetic field) and other methods have been applied to the determination of the electronic structure of copper, silver and gold. During the last few years it has been possible to examine thin metal foils under the electron microscope and to observe, directly, dislocations present in the lattice that largely govern the mechanical properties of the metal. The exhibit shows dislocation behaviour and illustrates the interactions produced by cold working, alloying, fatigue and by nuclear irradiation.

Also in the Diploma Galleries there is a display, organised by the department of physics, Imperial College of Science and Technology, devoted to the physics of fundamental particles. The exhibit traces the early history of this branch of physics and illustrates some recent developments. It consists mainly of photographs of cloud-chamber and bubble-chamber experiments and and includes a summary of the main properties of the known fundamental particles and anti-particles.

Another exhibit simulates the continuous counter-current solvent extraction of plutonium, and shows (by a model) the primary separation plant which was built by the U.K.A.E.A. at Windscale, to a design formulated in September 1947, solely on the basis of semi-micro-scale laboratory experiments. This full-scale separation plant has since been working with an availability of about 300 days per annum.

There are also exhibits concerned with refined chemical separation (for example by chromatography and ion exchange) ; with the use of X-ray analysis and electron microscopy in revealing the molecular structure of biological systems ; with abnormal haemoglobins and human chromosomes, natural selection, microbial genetics, antibiotics and vitamins ; with the physiological and biochemical aspects of plant growth ; and with electrophysiology.

Conference on Machine Tool Design and Research

A MACHINE tool design and research conference is to be held in the Department of Mechanical Engineering of the University of Birmingham between September 26 and 30 next. This conference has been organised by a committee under the chairmanship of Professor S. A. Tobias, head of the Department of Mechanical Engineering, and will be in two parts, comprising introductory sessions on September 26 and 27, and main sessions on September 28, 29 and 30. A series of lectures given during the introductory sessions will summarise the existing state of knowledge in the three fields with which the main sessions will be concerned. These lectures will be given by members of the teaching and research staffs of the Departments of Mechanical Engineering of the University of Birmingham and the Manchester College of Science and Technology.

The three fields dealt with in the main sessions will be concerned with machine tool vibration ; metal cutting ; and mechanical engineering automation. At each session two papers surveying the subject will be presented and in each case they will be followed by papers dealing with particular aspects of research.

During the conference the laboratories of the Department will be open to inspection and research work in progress demonstrated. The number of delegates will be limited to 200, and we are informed that registrations, which should be addressed to the organising secretary at the University of Birmingham before September 1, 1960, will be accepted strictly in order of arrival.

Launch of H.M.S. " Ghurka "

(BY OUR NAVAL CORRESPONDENT)

IT is now clear that nuclear propulsion has transformed the underwater craft from a vessel which has the power to submerge when required, and is, in fact, a submersible, into a true submarine which habitually navigates and operates submerged at high speed. Whether it is a priority requirement for surface warships in view of the very high cost of installing and operating this revolutionary power plant has yet to be decided. It is thus highly satisfactory that British engineers have produced another revolutionary and far less costly type of propulsion machinery for our new surface warships which will considerably increase their operational efficiency—a combined steam and gas turbine plant. On July 11 the third ship of the Royal Navy, and the second vessel of frigate type, to be equipped with this plant—H.M.S. " Ghurka "—was launched at the Woolston shipyard of John I. Thornycroft and Co. Both the steam and the gas turbines are geared to the same shaft, the gas turbines providing a high concentration of power in a very compact form. Our latest ships will thus have a large reserve of power for use when required to boost the steam turbines for sustained periods of high speed. Equally important, in these days when the advantages of a successful surprise attack are still believed to be a sufficient incentive for the use of thermo-nuclear weapons, gas turbines will enable a vessel to get under way at a few minutes' notice when steam is not available. The design of the machinery, which is remotely controlled at all powers, was evolved by close co-operation between the Admiralty, Messrs. Yarrow and Co., and Associated Electrical Industries, Ltd.

H.M.S. " Ghurka "—a ship of about 2500 tons, 360ft in length, with a beam of 42ft 6in and of all-welded prefabricated construction—is the second of the seven " Ashanti " class General Purpose Frigates ordered in the Navy Estimates of 1955–56, 1956–57 and 1957–58. The first—H.M.S. " Ashanti "—was launched a year ago. The " Ghurka " was laid down in November, 1958, and will probably take another eighteen months to complete. Three years seems a long time for the construction of a relatively small vessel of 2500 tons, especially for a firm such as John I. Thornycroft, Ltd., which specialises in the building of small ships of this type. But technological developments since the war have resulted in a substantial increase in complicated equipment and only those who are familiar with the job of constructing a new warship to-day can realise what this means in terms of cost and building time. Even during

the construction of a ship staff requirements change and necessitate the replacement of equipment, already installed, with a new design. Moreover to reduce manufacturing costs and provide for the availability of spare parts at short notice, standardisation of equipment has become essential. This, in fact, means that warship builders are, to a much greater extent than in pre-war days, assemblers as well as constructors and it is difficult to co-ordinate all the sub-contractors and arrange that material, units and equipment will be available in the right sequence when required for building against a pre-arranged schedule.

H.M.S. " Ghurka " and her class are designed to carry out the functions of escort frigates, but will, in fact, be suitable for " the maid-of-all-work " duties carried out by our existing destroyers built during the war. So long as N.A.T.O. still visualises the possibility of a total war in Europe, it must be difficult for the Chiefs-of-Staff to decide on the most suitable type of vessel for trade protection. But it seems likely that apart from aircraft direction frigates, which are intended primarily as radar picket vessels for the direction of carrier-borne and shore-based aircraft, frigates of the future will be designed on the lines of the " Ashanti " class—the first frigates to carry a helicopter for anti-submarine purposes. They have a powerful anti-submarine armament of triple barrelled depth charge mortars and two 4·5in guns in single mountings —a departure from the practice hitherto of twin mountings—controlled by a radar-operated fire control system, for dealing with both surface ships and aircraft. Two 40mm Bofors guns complete their anti-aircraft armament, but these are likely to be replaced in due course by the short-range " Seacat " guided weapon launcher. These frigates are also to have the latest mark of warning radar. Air conditioning has been installed in all major compartments, such as the enclosed bridge, the large operations room and all living spaces, which suggests that these ships may well be used in peacetime to replace the seven wartime frigates at present earmarked for duties in the Persian Gulf area. Denny Brown stabilisers are being installed and accommodation and amenities for the ship's company will include bunk sleeping, cafetaria messing and power points for personal electrical equipment. The naming and religious ceremonies at Southampton were performed respectively by the Lady Carrington—wife of the First Lord of the Admiralty—and the Bishop of Southampton, in the presence of H.R.H. the Crown Prince of Nepal.

New Instrument Landing System at London Airport

WORK has been completed on the first installations of the STAN 7/8 Instrument Landing System at London Airport. This equipment, designed and manufactured by Standard Telephones and Cables Ltd. Connaught House, Aldwych, London, W.C.2, has been installed at the airport on No. 1 runway, North parallel. Further equipment will be supplied for No. 5 runway, South parallel.

The apparatus is claimed to represent a major advance in I.L.S. ground equipment techniques in respect of beam stability and equipment reliability. There are three main elements in the London Airport installations : the localiser, for azimuth guidance ; the glide path, for elevation guidance ; and the monitoring and remote control equipment for system supervision. No. 1 runway is equipped for landings from either direction and has two separate and independent sets of equipment. The localiser (STAN 7) operates on any one of thirty-nine channels within the 108·1 to 111·9 Mc/s band. Its transmitter consists of two identical r.f. and modulator sections which feed two independent aerial arrays (Fig. 1). The composite radiation pattern consists of two signal zones from the main " course " array, plus two signal zones from the smaller " clearance " array, modulated at 90 and 150 c/s and lying on either side of the runway centre line. The basic frequencies of the two course and clearance arrays differ by 9·5 kc/s.

The clearance pattern is, in effect, a rough guide to the pilot as to which side of the approach runway he is flying. Upon reaching the narrow " course " radiation pattern his receiver takes up and indicates the information from this narrower and stronger beam.

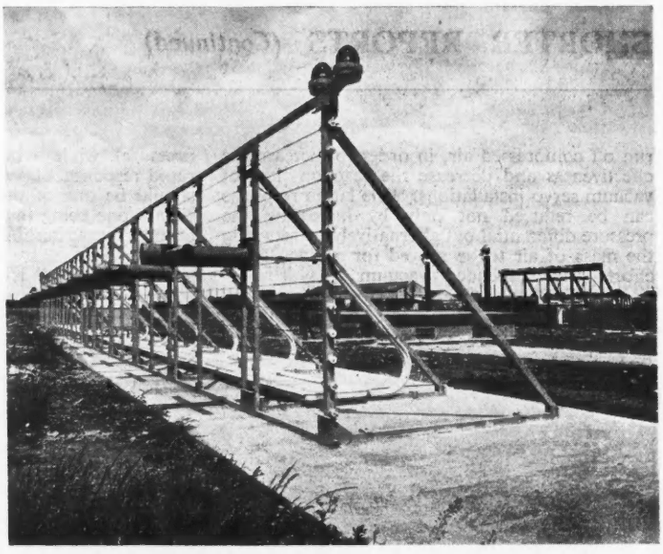


Fig. 1—Course aerial (foreground) and clearance aerial arrays of I.L.S. installation at London Airport

The clearance array provides non-ambiguous and useful navigational information throughout 360 deg., and, in addition, a " back course " to facilitate navigation into the front course.

Operated on any one of twenty-one preset channels, the glide path equipment (STAN 8) gives guidance information in the vertical plane to enable the aircraft to arrive at the correct height over the end of the runway. The r.f. and modulator sections of the glide path equipment are basically similar to a single section of the localiser transmitter. The composite aerial (Fig. 2) radiates, on a common frequency, two patterns modulated at 90 and 150 c/s. This produces two signal zones lying above and below and overlapping the desired glide path.

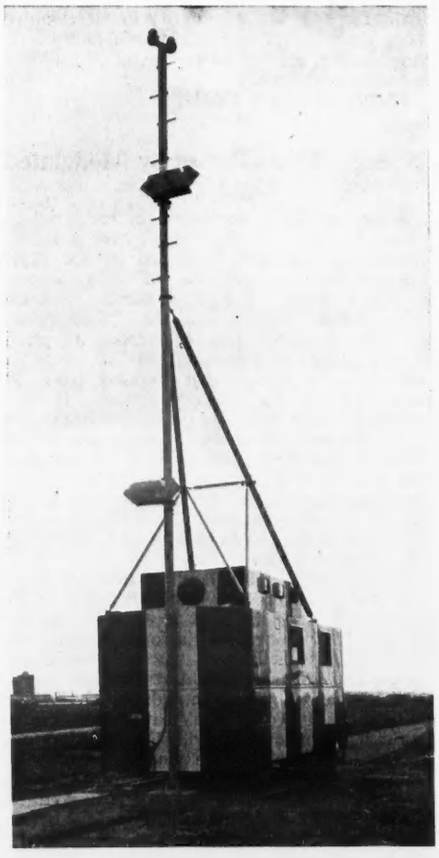


Fig. 2—Composite aerial array for glide path pattern in the London Airport I.L.S. installation

A constant-impedance double-sideband mechanical modulation system is employed in the STAN 7/8, for which considerable advantages are claimed in that, apart from its substantially constant input impedance, it is relatively simple and not subject to variations which may occur due to the ageing or failure of components.

Characteristics of the STAN 7/8 system are improved freedom, compared with other static systems, from course bends resulting from site imperfections, and from the dangers of radiating false course information. This is achieved by the use of an extremely narrow beam for course guidance, and the clearance radiation pattern which effectively masks any reflections which may arise from secondary lobes. In addition to these features, overall system reliability is safeguarded by a comprehensive, fully transistorised fail/safe monitoring system linked to a fully automatic changeover unit.

[Reply Card No. E2091]

Air Powered Hydraulic Servo

IT is widely acknowledged that a volume of air under a pressure differential forms a convenient tool for tapping and storing energy from a vehicle engine, but that for vehicles with small to medium size wheels hydraulic brake actuation is most convenient. To utilise the two different media for obtaining and applying power, the Clayton Dewandre Company, Ltd., of Lincoln, some years ago commenced to manufacture under licence from the Bendix Westinghouse Company a system in which the pneumatic brake motors of an ordinary air brake system were replaced by the master cylinder of a hydraulic brake system.* This system employed a great number of standard pneumatic components, but it retained the characteristic of " no air, no brake. " Clayton Dewandre has now introduced a new air-hydraulic system in which compressed air acts merely to give servo assistance to a simple hydraulic system ; thus loss of air pressure ceases to be catastrophic, although it becomes very much more expensive to incorporate a plurality of separate hydraulic circuits. This system is in principle the same as a " vacuum " hydraulic servo, and it has been designed so that the compressor and " Airpak " are mechanically interchangeable with an exhauster and " Hydrovac."

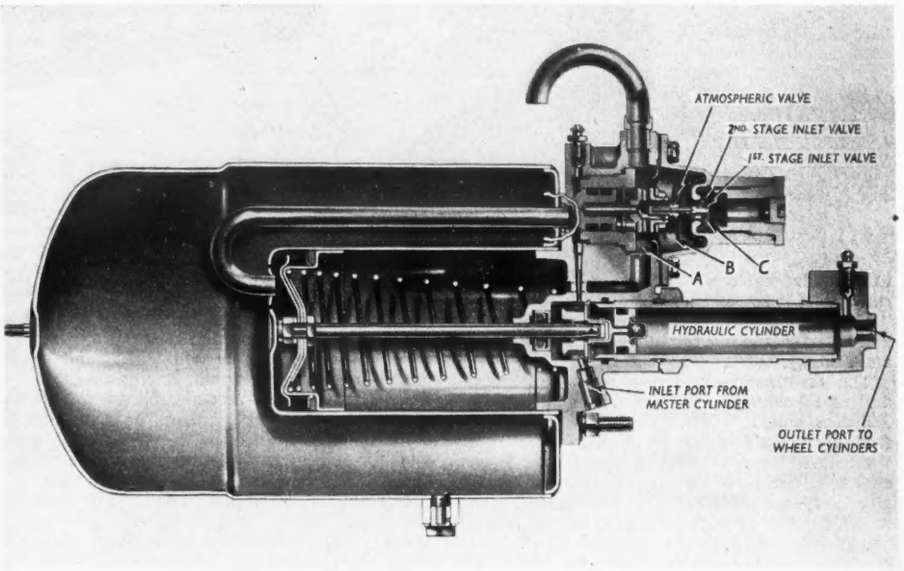
In this context it is interesting to recall that Clayton Dewandre have been supplying conversion kits to allow vacuum servo motors to

* " Lightweight Air Pressure Braking System," THE ENGINEER, August 26, 1955.

SHORTER REPORTS *(Continued)*

run off compressed air, in order to increase the effectiveness and decrease the reaction time of vacuum servo installations. The lag in response can be reduced not only by increasing the pressure differential but alternatively by reducing the mass of air to be moved for a given servo effort, and suspended vacuum " Hydrovac " pressure), while a heavy application can attain rapid response. Speed and delivery of response should be one of the main advantages, a subsidiary one being that the driver becomes aware of the increase in shoe travel due to wear or drum heating.

The " Airpak " is available with 1in or 1¼in



Compressed air brake servo, functionally analogous to and mechanically interchangeable with, a vacuum servo

units have been introduced on, for instance, the 7-ton Thames " Trader."

The new S.C.4 compressor has the same output as that of the earlier design of 4 cubic feet f.a.d. at 1250 r.p.m., but its maximum speed is only 2800 r.p.m. instead of 3000 r.p.m. ; two instead of one ball bearings are fitted at the drive end of the crankshaft, and in all cases it is lubricated from the engine supply, oil entering through the plain crankshaft bearing and passing through a drilling to the plain big end. A valve-in-head instead of e.o.i. arrangement is used, and the governor that actuates the unloader is now mounted on the compressor. Thus the long small-bore pipe from downstream of the non-return valve on the reservoir contains the slightly and slowly varying reservoir pressure and not the alternating pulses of atmosphere and supply pressure that emanate from the governor. The compressor shaft is tapered and keyed to couple to a fuel injection pump.

The remainder of the air pressure system consists of the " Airpak " illustrated. The outer envelope forms the reservoir and communicates with volume *C*. Within it is the air power cylinder, the working end connected by the control tube illustrated to volume *B*, and the other end open, as can be seen, to *A*. Hydraulic pressure generated at the master cylinder moves the diaphragm assembly to the right, first closing the atmospheric valve and then opening the inlet valve. Air then passes from *C* to *B* and drives the piston to the right, until the pressure in *B* rises sufficiently to balance the hydraulic pressure and close the inlet valve. The intrusion of the piston-rod into the hydraulic cylinder moves the hydraulic piston away from the end of the cylinder and a ball valve within it is allowed to seat : henceforward the force on the hydraulic piston is the sum of those due to the master cylinder pressure and the air power cylinder pressure.

The inlet valve opens in two stages, so that a slow admission of air can be obtained with a small pedal effort (about 40 lb per square inch oil hydraulic and 3in, 4in, or 4½ in air cylinders. They are supplied with seals suitable either for vegetable or, painted blue, mineral oil—never, it is emphasised, both.

[Reply Card No. E2092]

Speech Transmission by Modulated Light Beam

A COMMUNICATIONS system for industrial use where messages can be passed over a line-of-sight path has been developed by the Radio Communications Division of The General Electric Company, Ltd., Ford Street, Coventry. The system, known as the " Optiphone," provides a speech link of normal telephone standard over distances up to 200 yards by modulating a light beam directed from the transmitting to the receiving station. It could be installed, for example, on an overhead crane track, the transmitter being fixed at one end of the track and the receiver mounted on the crane. The two-wire connection between the microphone and the transmitter can be of any reasonable length, allowing flexibility in the positioning of the transmitter so as to have an unobstructed path to the receiver.

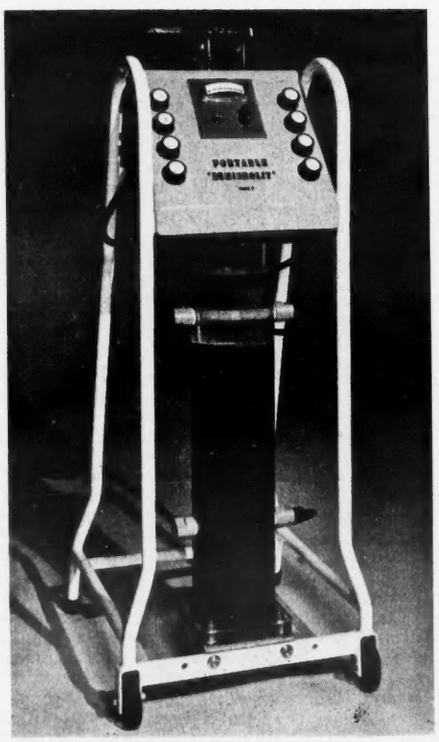
An Osram 6V, 60W lamp as used for sound reproduction from film tracks is fitted in the transmitter and its light output is beamed towards the receiver. This form of lamp was chosen because its filament structure is sufficiently robust for industrial use but at the same time its light output can follow modulation frequencies up to about 3000 c/s. A 6V battery is connected to the filament in series with the recording of a modulation transformer having its primary fed from a push-pull amplifier in the same unit. A changing circuit is included in the unit and is automatically switched in to maintain the battery at or near full charge when the microphone is not in use.

The receiver has a honeycomb window to cut out interference from light entering from directions other than that of the transmitter, behind which is a lens focusing the transmitter beam on to a photo-transistor. The transistor output, which is proportional to the intensity of the light falling on it, is fed via an emitter follower to the drive stage of a push-pull amplifier transformer coupled to a loudspeaker. This unit is completely transistorised and operates from a 12V accumulator independently of a mains supply. Where the system is used for communication from a fixed to a mobile point, transmitter and receiver may be slightly offset so that the receiver picks up the full beam intensity at maximum range but becomes displaced from the centre as it approaches the transmitter. The equipment was demonstrated to us recently, and we understand that it could form the basis of a remote control system by transmitting a series of fixed modulation frequencies instead of a speech signal.

(Reply Card No. E2101).

Small Portable Water Purifier

THE accompanying illustration shows a new portable " Deminrolit " equipment designed and manufactured by the Permutit Company, Ltd., Gunnerbury Avenue, London, W.4, for converting up to 12 gallons hourly of clean cold water into demineralised water having a conductivity of less than 1·0 reciprocal megohm per centimetre. It is stated that the quality of water produced conforms to the " purified water " standard of



12 gallons per hour capacity portable water purifier

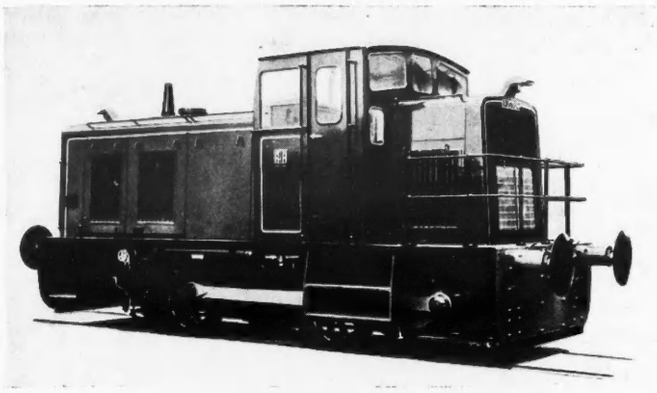
the British Pharmacopoeia, 1958. The unit is essentially a mixed bed ion exchanger, the ion exchange materials used being the maker's " Zeo-Karb 225 " and " De-Acidite FF." A conductivity tester fitted on the equipment continuously monitors treated water quality.

Constructed as a free-standing unit of non-corrodible design, this Mark 6 portable " Deminrolit " is suitable for workshop as well as laboratory conditions. It is simply connected to the water supply by flexible hose.

[Reply Card No. E2102]

Diesel-Hydraulic Industrial Shunter

WITH the introduction of the " LSSH " diesel-hydraulic shunting locomotive, a unit for the heavier haulage duties at steelworks, electric power stations and other industrial undertakings has been added to the shunter range of Ruston and Hornsby, Ltd., Lincoln. This 275 h.p. locomotive is powered by a Paxman six-cylinder " RPHL " 1360 r.p.m. vee engine coupled to a " Twin Disc," Series 13,800, three-stage torque converter. The weight is 34 tons, and as a 0–4–0 it can be built for gauges from 4ft 8½in to 5ft 6in. During a visit to the builder's works on July 21 several of the locomotives were seen under construction for the Siderurgia Nacional, Portugal, to the 5ft 6in gauge. If built as an 0–6–0, the " LSSH " can be supplied for gauges from 3ft 6in to 5ft 6in. Choice of the torque-converter transmission was governed by information gained from market research that there is a preference for stepless transmission and its better utilisation of engine power in the range of more powerful locomotives. A diesel-electric version is under development and expected to be ready next year. It will be intended particularly for service where a large proportion of the running will be in the upper end of the speed range, where electric transmission has some advantage in efficiency over a hydraulic system. In its present diesel-hydraulic form the locomotive has a maximum starting traction effort of 23,000 lb and a top speed of 18 m.p.h.



Industrial diesel shunting locomotive with torque converter drive

Referring to the accompanying illustration, the shorter bonnet behind the cab contains the reversing gearbox, which is coupled to the engine and torque converter under the front bonnet by a " Layrub " cardan shaft passing under the cab floor. This arrangement was adopted in order to reduce the length of the front bonnet and improve visibility from the cab.

A demonstration run on one of the locomotives showed the simplicity of the driving controls and freedom of movement in the cab. The speed, reverse and brake controls are duplicated, consisting of two groups of three levers extending into the cab through vertical apertures in the front wall. All rods, cranks and connections are on the bonnet side of the wall in order to leave the cab unobstructed. The power lever is moved upwards to accelerate the locomotive. During the first part of its travel it controls an air-operated clutch between the engine and torque converter, and subsequently accelerates the engine through a " Teleflex " drive to the governor. An interlock prevents the reverser from being moved until the locomotive is stationary. This takes the form of a pump in the gearbox ; while moving it holds up a piston to keep an air valve closed. When the pump stops the valve opens and air pressure releases a mechanical interlock which then allows the reverser to be thrown by its own air piston. Similarly the interlock cannot be released unless there is adequate air for operation of the Westinghouse brake. The air supply is provided by a " Broomwade " compressor belt-driven from the engine.

Sanding is controlled by a spring-biased lever which is moved to left or right according to the direction of travel. In addition to the normal air injector, jets are fitted to ensure that the sand is directed under the wheels in windy conditions.

Instrumentation is comprehensive, the nine instruments grouped on a panel in the centre of the cab front wall including torque compressor oil temperature and oil pressure gauges and a compressor lubricating oil pressure gauge. Audible fault warnings are also available. The panel is sloped for convenient visibility, but with only a small projection into the cab. A separate panel carries electrical switches and the battery ammeter for the 24V d.c. charging, starting and lighting system. The cab layout as a whole was designed to avoid obstructions which might hinder the driver's movements while shunting and for this reason conventional forms of control desks or pedestals were avoided.

The drive from the gearbox is by a toothed coupling to a jackshaft carried in separate Timken bearings in the main frame to relieve the gearbox of stresses. Side thrust from the wheels is taken by thrust faces on the inside of the single-flange axleboxes in contact with split thrust collars on the axles, this arrangement giving better protection of the faces from dirt. The collars are easily dismantled for allowing axleboxes to be withdrawn inwards when inspection of bearings is required, it being necessary only to take the weight of the locomotive while this is being done instead of lifting it to drop the running gear.

[Reply Card No. E2111]

Mobile Plate Lifting Machine

A MACHINE for lifting and placing sheets of steel, plate glass, wall cladding, or other types of reasonably smooth sheet material, introduced by the Hill Brothers Glass Company, Ltd., of Birmingham, is manufactured by Thos. Adshead and Son, Ltd., Queen's Cross, Dudley, Worcs. This machine, to be seen in the accompanying illustration, was originally developed for manipulating large sheets of plate glass into ground level or overhead window frames and is known as the Hill's " Robot Plate-Lifter." It is hydraulically operated and consists basically of a long jointed arm mounted on a turntable on an electric truck. At the end of the arm, four vacuum faceplates, giving a grip of approximately 900 lb, are carried on a 5ft by 6ft box-section frame. The sheets are securely held by the faceplates and can be lifted up, down, across or swung around through 180 deg. under the guidance of the operator standing by the controls on the turntable. Precise positioning of sheets is made possible by the use of further individual movements of the vacuum head and the faceplates themselves. In the travelling position, its arms are folded down along the truck.

The machine has a maximum working load of 560 lb and the maximum height available between the centre of the vacuum head and ground level is 24ft. The length of horizontal extension available from the centre line of rotation to the front of the faceplates is 15ft 6in.

[Reply Card No. E2112]

Breakdown Agent for Carbon Dioxide/Sodium-Silicate Moulding

IN the carbon dioxide/sodium silicate moulding process, there is a direct relationship between the casting temperature, the strength of the sand bond required as a consequence, and the difficulties of sand breakdown after casting. To obtain the appropriate strength of bond, the sodium silicate percentage must be varied, being smallest for aluminium alloys and greatest for steel. A higher proportion of silicate gives increased strength but increases correspondingly the difficulty of breakdown. For this reason the Distillers Company, Ltd., Devonshire House, Mayfair Place, London, W.1, has introduced " Frecor," a breakdown agent based on ammonium chloride, designed to overcome the breakdown problem without premature weakening of the bond or tendency to produce friability on the faces of moulds and cores.

The agent is supplied in two forms, " Frecor b " and " Frecor w," the former being intended for use with core shooters and blowers and the latter with hand or mechanical ramming methods. It is used generally at the rate of 1 to 1½ per cent by weight of sand where 3½ per cent sodium silicate is employed. A lower silicate content enables corresponding savings in " Frecor " and for high strength requirements, which necessitate increased usage of silicate, a more than corresponding increase of agent may be needed.

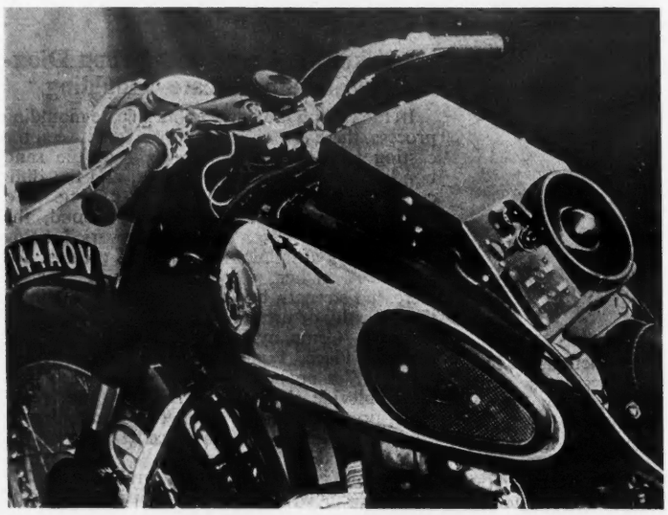
It is stated that when using the breakdown agent on core shooters and blowing equipment the mixing time for sand and silicate should be as short as possible, and during this operation " Frecor b " should be sprinkled evenly over the mix. When ramming by hand or using sand slinger or jolting equipment, the mixing time for sand and silicate should again be as short as possible—usually about one minute. The recommended " Frecor w " should be introduced to the mould or core as work proceeds, being placed approximately ¼in to ⅜in from sand/metal faces. Where cores are nearly totally enclosed by the cast metal the placing of some " Frecor " in the centre of that part of the core will assist complete breakdown of the bond in those parts of the cores difficult to remove after casting.

Mobile plate lifting and positioning machine being used for inserting large plate glass windows

SHORTER REPORTS *(Continued)*

Motor-Cycle Police Radio

TWO-WAY v.h.f. frequency-modulated transmitter-receivers now being supplied by The General Electric Company, Ltd., Magnet House, Kingsway, London, W.C.2, to the Lancashire Police, are designed for transmit-receive switching without the user having to move his hands from the handlebars. The controls, shown in the accompanying illustration, comprise a tank-mounted unit and a transmit-receive button by the left-hand grip. A special microphone earpiece has been designed for use with this equipment, incorporating a moving coil microphone, shielded to avoid extraneous sound interference, and one earpiece in a light, padded frame. The unit slips under the crash-hat strap with stud-fixing. The connection to the tank unit is located by small studs and held magnetically so as to be released immediately by any sudden jerk.



Location of v.h.f. transmitter-receiver controls on police motor-cycle. The transmit-receive push button is adjacent to the left-hand grip

The whole radio unit weighs only about 31 lb, fairly evenly divided between the tank and the rear-mounted carrier. With a well-sited main station, the range varies from about 45 to 90 miles depending on the type of country. Twenty transistors are used in the transmitter-receiver unit (mounted in the pillion position), resulting in low consumption from the normal 6V motor-cycle battery. On "receive" the consumption is approximately 0·8A, increasing to about 10A on "transmit." The equipment operates in the 80-100 Mc/s range and is being made to the design of the Lancashire County Police Laboratories.

(Reply Card No. E2121)

Bottling Plant in Dublin

BATCHELORS, Ltd., recently decided to expand its present bottling plant to include the bottling of soft drinks and the new plant, which is located in close proximity to the existing facilities, was officially opened on July 4. The building was the responsibility of Mr. S. J. Hurd, while the engineering work was carried out by the Worssam Products division of Vickers-Armstrong (Engineers), Ltd. The plant is arranged to handle 6½ oz "split" and 4 oz "baby" bottles at a rate of 550 dozen bottles per hour of the latter size, and the associated water treatment and syrup preparation plants are in separate rooms within the bottling hall, of which we include a general view.

Water for bottling is drawn from town supply and treated in a Permutit batch "Precipitator" plant, having a capacity of 250/1000 gallons per hour, and then passed through a Carlson portable sterile sheet filter and cooled in an A.P.V. "Paraflow" 670 gallons per hour heat exchanger using brine at 22 deg. Fah. The chilled water is stored in an insulated tank, of 2400 gallons capacity, from where it passes through a final sterile Carlson filter, of 300 gallons per hour rating, to the carbonator. Water for syrup making after precipitator treatment and filtering passes direct to the two 3400-gallon mixing tanks.

The syrups are prepared in two 400-gallon stainless steel steam jacketed mixing and pasteurising tanks having motor-driven agitators, and then passed through a portable sterile sheet filter of 400 gallons per hour capacity. They are cooled in an A.P.V. stainless steel heat exchanger able to deal with 400 gallons per hour and then transferred to cold storage and held at 45 deg. Fah. in three 400-gallon tanks, each equipped with motor-driven agitators. The temperature is maintained by a York Shipley automatic "Freon 12" refrigerating plant. Automatically controlled positive displacement pumps transfer the syrup to a 15-gallon insulated balance tank.

The bottling plant consists of a Dawson twelve wide "Hydro" bottle washing machine having a semi-automatic feed board and an automatic discharge, and having three detergent sections. A Permutit diaphragm pressure chlorine dosing plant capable of dealing with 1000 gallons per hour treats the final rinse water which also passes through a portable sterile sheet filter of like capacity. Empty bottles are supplied to the washing machine by a Pantin gravity roller case conveyor and placed by hand on to the semi-automatic feed board of the washer. After inspection the bottles are carried on a Worssam slat chain conveyor to the Worssam filling unit consisting of a ten head syruper where the bottle receives the correct quantity of syrup ; a thirty head carbonated water filler which adds water to a controlled level ; and an eight head crowner. After being crowned the bottles are conveyed to a sixteen head Miller Kendall automatic rotary beverage mixer where the contents are thoroughly mixed by mechanical agitation. Following another inspection the filled bottles are labelled and discharged on to an accumulating table ready for hand loading into cases.

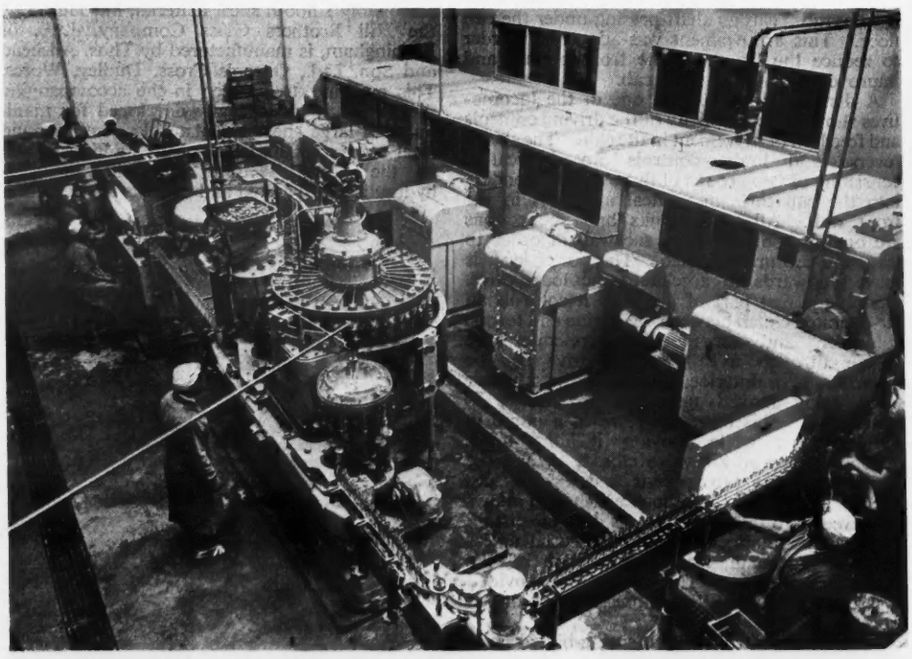
Auxiliary equipment includes two Worthington-Simpson direct coupled centrifugal pumping sets, a "Broomwade" twin-cylinder, 6in by 6½in air compressor complete with cooler and air receiver, and an air sterilising filter.

[Reply Card No. E2122]

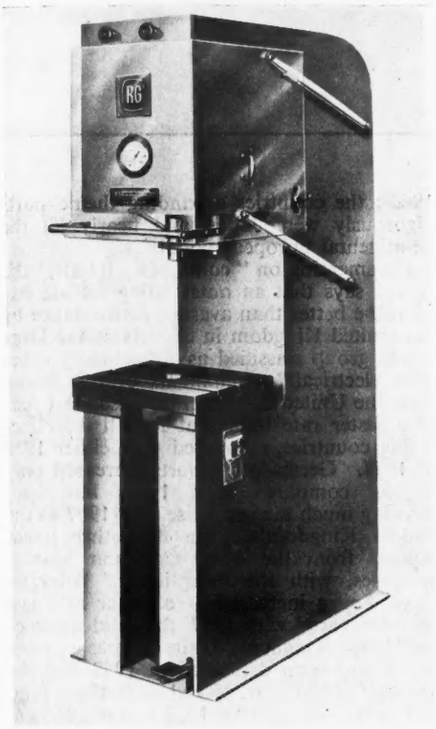
Hydraulic Presses

A NEW range of high-speed hydraulic presses designed and built for Dowding and Doll, Ltd., 346, Kensington High Street, London, W.14, by Rhodes, Gill and Co., Ltd., includes three models of 5, 10 and 15 tons capacity. The presses are of self contained design with the hydraulic reservoir, pump, motor, and all pipe work and control rods enclosed within a fabricated steel frame of sturdy design.

On all three models, operating pressure and slow ram advance for setting purposes are controlled by a regulator fitted close to the pressure gauge, for which an isolating valve is provided. Both the ram nose and the table are designed to accept most forms of tooling and the transparent plastics guards fitted allow a clear view of the work



Bottling hall with the washing machine in the background and the filling unit in the foreground



15-ton capacity hydraulic press

The 5-ton machine, which has a stroke of 4in, can be supplied either as a bench press or fitted on a pedestal for floor mounting. It is operated by a handrail which extends across the front of the press and the pedestal model can also be supplied for foot operation. An accumulator system provides means of rapid ram approach with instantaneous speed reduction and the application of full operating pressure immediately the load is applied. The use of a double-acting cylinder provides positive power ram return. The speed of the ram on the approach, pressing and power return strokes is 1000in, 35in and 650in per minute respectively.

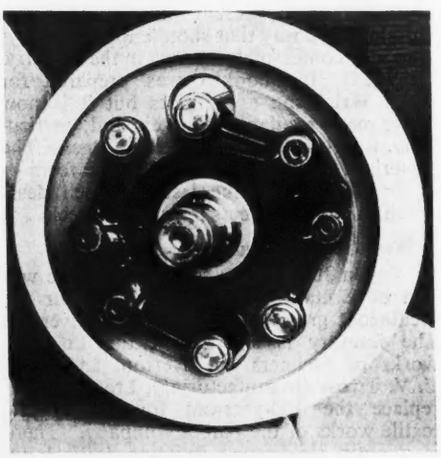
Both the 10-ton and the 15-ton machines operate on the jack-ram prefill system, and have strokes of 8in and 10in respectively. A device can be fitted to limit the downward stroke which is readily adjustable by means of a knurled wheel projecting from the side of the press and this device permits accurate inching of the ram.

The speed of the ram on the standard 10-ton model is 390in, 35in and 186in a minute on the approach, pressing and power return strokes respectively. The corresponding speeds for the 15-ton model, which is shown in our illustration, are 390in, 21in, and 140in per minute. On the smallest press, which has a 7in deep throat, the height between the table and ram is 12in ; on the larger capacity machines, with throat depths of 9in and 10in respectively, the table to ram heights are 16½in and 19½in. The table sizes are 14in by 11½in (5-ton) ; 16in by 14in (10-ton) ; and 18in by 16in (15-ton press).

[Reply Card No. E2123]

Motors for A.C. Locomotives

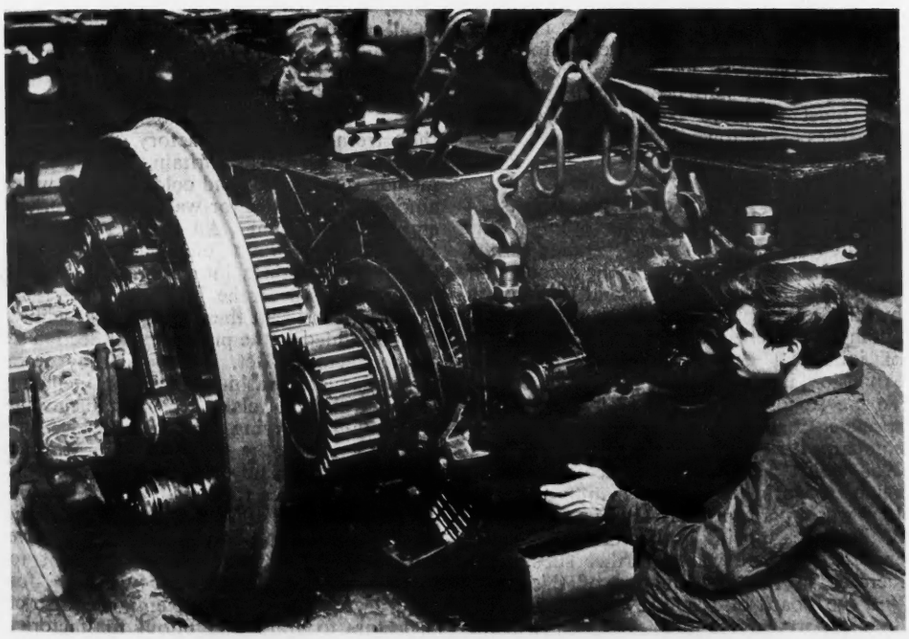
TEN of the thirty-five 3300 h.p. a.c. locomotives being supplied to British Railways by the traction division of Associated Electrical Industries, Ltd., are being built at the Gorton Works of Beyer Peacock, Ltd. We illustrate an 847 h.p. traction motor for one of these locomotives being fitted to a wheel and axle set. The motor is, in general, a normal d.c. machine, but to enable it to operate satisfactorily with the a.c. ripple, non-inductive resistances have been fitted across the field coils. Such an arrangement allows the a.c. components to be by-passed from the motor fields, while the connecting together of the poles themselves by means of a laminated ring inside the yoke casting ensures that the interpole flux and armature current are kept in phase with each other. The ratings are : Continuous, 975V, 700A, 847 h.p.; One-hour, 975V, 760A, 920 h.p.



Locomotive driving wheel, showing flexible link system for transmission of drive from a spider behind the wheel

The four motors in each locomotive are fully springborne in the bogies, the drive being transmitted to the road wheels by an Alsthom quill drive. This is seen outside the driving wheel in the lower illustration and is shown in more detail in the separate view of a wheel. The drive is transmitted through links between two driving members (which project through openings in the wheel web) and opposite corners of a floating member. The other corners of this member are connected by similar links to the wheel web. The axle rotates with sufficient clearance inside a hollow shaft carrying the gearwheel and driving member to allow for relative movements due to the bogie springs. These movements are accommodated by the system of driving links and floating member, the joints in which are formed by " Silentbloc " bushes and do not require lubrication.

[Reply Card No. E2131].



Traction motor and drive for British Railways a.c. locomotive

Technical Reports

A Sensitive Direct-Reading Pocket-Size Gamma Dosimeter. (A.E.R.E.—R3115.) By J. H. Howes (A.E.R.E., Harwell). H.M. Stationery Office. Price 3s.—The instrument described in this report was developed to meet the need for a direct-reading dosimeter, with a sensitivity of about 20mR, suitable for carrying in a laboratory coat pocket. This instrument measures gamma radiation dose by using a simple condenser ionisation chamber. The self-capacitance of the electrodes of the chamber provides the necessary charge storage and the volt drop during gamma irradiation is directly proportional to gamma dose. The change in voltage across the ionisation chamber is measured by a single electrometer valve circuit. A full explanation of the operating principles, together with a description of the circuit and instrument design, is given in the report.

Resonance Integral Calculations for High-Temperature Reactors. By J. P. H. Blake (U.K.A.E.A. Research Group, Winfrith) H.M. Stationery Office. Price 5s. 6d.—Methods of calculation of resonance integrals of finite dilution and temperature are given for both homogeneous and heterogeneous geometries, together with the results obtained from these methods as applied to the design of high-temperature reactors. In this report reference is made to a " Monte Carlo " calculation of the resonance escape probability in a lattice consisting of pellets of resonance absorber embedded in moderating material. An addendum gives further details of this calculation, and explains its relationship to a similar calculation for the resonance absorber (U238) considered in another U.K.A.E.A. report (A.E.R.E.–R2929).

Launches and Trial Trips

BRITISH MALLARD, oil tanker ; built at Belfast by Harland and Wolff, Ltd., for the B.P. Tanker Company, Ltd.; length between perpendiculars 495ft, breadth moulded 69ft, depth moulded 37ft, deadweight 15,200 tons (summer draught), 13,650 tons (service draught) ; twenty-seven cargo oil tanks, two cargo pump rooms, two 250kW diesel-driven generators, one 75kW steam-driven generator ; Harland and Wolff, single-acting, two-stroke, opposed-piston oil engine, six cylinders 750mm bore by 200mm combined stroke, 112 r.p.m., two oil-fired and one exhaust gas-fired boilers. Trial, May 9.

CITY OF WORCESTER, cargo liner ; built by the Caledon Shipbuilding and Engineering Company, Ltd., for Ellerman Lines, Ltd.; length overall 434ft, breadth moulded 59ft, depth moulded to shelter deck 36ft 9in, deadweight 8500 tons on 26ft 2in draught, sea speed 14½ knots ; four holds, ten cargo derricks for 7-ton and 10-ton loads ; three 180kW diesel-driven generators; Clark-Sulzer, single-acting, two-stroke diesel engine, eight cylinders, 5040 b.h.p. at 121 r.p.m. Launch, May 12.

THALASSA, ocean research ship ; built by Chantiers et Ateliers Augustin Normand for the merchant marine ; length between perpendiculars 56.5m, breadth moulded 10.4m, depth moulded to main deck 4.45m, displacement 1480 tons ; speed 12 knots, static pull 13.5 tons, pull at 4 knots 10 tons; three 150kVA alternators ; an eight-cylinder diesel engine, 800 h.p. at 375 r.p.m., and one six-cylinder engine of 300 h.p. at 600 r.p.m. Launch, May 8.

INDUSTRIAL NEWS

Apprentices Wages

Recent negotiations on wage rates for apprentices in the engineering industries have now been concluded. An agreement between the Engineering and Allied Employers National Federation and the Confederation of Shipbuilding and Engineering Unions provides for wage increases for all apprentices, ranging from 3s. 10d. a week at the age of fifteen to 17s. at the age of twenty. These increases are to be added to the apprentices' supplementary payments and do not alter the system of calculating their basic rates. Apprentices' basic wages are computed as a percentage, varying according to age, of the rate paid to skilled fitters. The new agreement took effect last Monday.

Merchant Shipbuilding Returns

The Shipbuilding returns for the quarter ended June 30 have been published by Lloyd's Register of Shipping and state that in Great Britain and Northern Ireland the work in hand amounted to 261 ships of 1,866,288 tons gross, the lowest figure since September, 1946. Included in the total are 55 oil tankers of 895,175 tons gross or 48 per cent of the ships building, and 31 ships of 238,835 tons, or 14·7 per cent of the total, for registration abroad. During the quarter the totals of ships commenced, launched or completed totalled 69 ships of 273,613 tons, 71 ships of 345,958 tons and 76 ships of 377,477 tons respectively. Abroad, the work in hand totalled 1203 ships of 7,257,887 tons gross, the leading countries being Japan with 981,026 tons and Germany with 929,826 tons. Oil tankers accounted for 188 ships of 3,463,438 tons gross or 47·7 per cent of the total under construction. Tonnage commenced, launched and completed amounted to 491 ships of 1,554,326 tons, 488 ships of 2,142,122 tons, and 459 ships of 1,721,248 tons respectively. Of the tonnage building 3,022,292 tons or 41·6 per cent were for export. Throughout the world 1464 ships of 9,124,175 tons gross were under construction of which 20·5 per cent are being built in Great Britain and Northern Ireland. Oil Tankers accounted for 243 ships of 4,358,613 tons or 47·8 per cent and the tonnage building for export totalled 3,261,127 tons. Of this all the steamships and motorships under construction, 4,900,147 tons or 53·7 per cent are to be classed with Lloyd's Register.

Unemployment

The Ministry of Labour reports that on July 11, there were 291,919 people registered as unemployed in Great Britain, of whom 281,747 were wholly unemployed and 10,172 temporarily stopped. Expressed as a proportion of the estimated number of employees, unemployment on July 11 was 1·3 per cent ; in June it was 1·4 per cent and a year ago it was 1·8 per cent. Between June 13 and July 11, the number of unemployed dropped by 13,208 ; there was a fall of 15,411 in the number wholly unemployed, but the number of " temporarily stopped " increased by 2203. The number of unemployed adults fell by 16,131, but there were 2923 more boys and girls out of work. The number of people registered as unemployed in Northern Ireland on July 11 was 28,520 which was 1036 fewer than a month earlier ; the July figure represents 6 per cent of the estimated total number of employees.

In the four-week period ended July 6, the Ministry of Labour says that the employment exchanges in Great Britain filled 155,912 vacancies. The number of vacancies notified to the exchanges but remaining unfilled on July 6 was 379,548, which was 18,668 more than in June. The normal seasonal change is an increase of about 17,000.

Careers in Iron and Steel

A booklet, entitled *Iron and Steel : Master of Them All*, has just been published by Head Wrightson and Company, Ltd. (price 5s.). Its author is Mr. Richard Miles, who recently retired from the chairmanship of the Head Wrightson group. He has set out " some elementary observations on iron and steel, on the iron and steel trade and on its history and present position in Great Britain " in a way that should appeal to boys who may contemplate a career in the industry. Originally, the booklet was prepared for Head Wrightson apprentices but it is now being made available to others and, particularly, to schools and technical colleges. The material is, in fact, presented in the form of twelve " lectures," the last of which deals specifically with careers in iron and steel.

West Country Foundry

On July 19, the foundation stone was laid of a new foundry being built for the Heathcoat group of companies at Tiverton. The foundry is situated at the Lowman works of Stenners of Tiverton, Ltd., and E. V. Twose (Manufacturing), Ltd., and will replace the 150-year-old foundry at the textile works of the parent company. There is a main single-span building 150ft long, 40ft wide and 20ft high, at one end of which there is a 40ft by 30ft fettling shop. The foundry, which includes the latest amenities, is designed for an output of about 700 tons a year. An interesting fact which was emphasised last week at the stone-laying ceremony is that an iron foundry has been operating continuously at Tiverton for more than 150 years. It was in existence before John Heathcoat started making lace in 1816 and must therefore be among the oldest industries in the town.

Export Trends

Trends in this country's exports of manufactured goods are surveyed in the current issue of the *Board of Trade Journal*. This survey explains that by the second half of 1959, some revival in demand for imports by the primary producing countries was adding to the effect of the general expansion of industrial activity to cause a strong expansion in world trade in manufactures. To see trends in trade in their proper perspective, it is essential in most cases to compare 1959 with 1957, rather than with 1958 which was a year of recession. The value of world exports of manufactures in 1959 was 8 per cent more than in 1957, most of the increase being in the volume of goods exported. There was a further substantial increase in the first quarter of this year. But, the Board of Trade says, United Kingdom exports of manufactured goods again increased less than the world average between 1957 and 1959 and in the first quarter of 1960 ; the countries expanding their exports vigorously were Japan and nearly all the Continental European countries.

Commenting on " commodity trends," the survey says that an outstanding feature has been the better than average performance by the United Kingdom in exports of the large mixed group classified as " machinery other than electrical." Shipments of this group from the United Kingdom increased last year at a faster rate than that for all manufacturing countries, compared with either 1958 or 1957. Germany's exports increased only slightly compared with 1958, but were showing much the same rise over 1957 as the United Kingdom's. On the other hand, exports from the other Common Market countries, with the exception of Belgium-Luxembourg increased at a faster rate last year compared with 1957, than did those of the United Kingdom. United States exports, which had been depressed in 1958 and the first half of last year, picked up in the second half of the year and for 1959 as a whole were marginally higher than in 1958, though still lower than in 1957. The United Kingdom also increased exports of metal-working machinery by much more than the average during 1959, though this was largely a reversal of the heavy fall in 1958. Compared with 1957, exports of metal-working machinery from the United Kingdom were little changed, as were those from the U.S.A ; Germany's exports in this category, however, were up by about 10 per cent. The United Kingdom's exports of electrical equipment in 1959 were 4 per cent higher than in 1958, which was about half the average rate for all manufacturing countries. Of the major exporting countries, both France and Germany last year registered gains of more than 20 per cent on 1957 and the Netherlands' exports were up by about 40 per cent. The outstanding feature however, has been the phenomenal continued increase in Japan's exports of electrical equipment which doubled between 1958 and 1959. On the other hand, last year's exports of electrical equipment from the U.S.A. were slightly lower than in either 1958 or 1957.

Washing Facilities in Factories

The Ministry of Labour has stated that from August 1 factory owners and occupiers in Great Britain will have to include running hot and cold or warm water among the facilities for washing for workers employed by them. An order entitled the Factories Act, 1959 (Commencement No. 2) Order, 1960, brings into operation on that day Section 18 of the Factories Act, 1959, which requires that these additional facilities shall be added to the provisions of Section 42 of the Factories Act, 1937, which lay down that adequate washing facilities including soap and clean towels or other suitable means of cleaning or drying, shall be provided and maintained. At the same time the Minister of Labour has laid before Parliament the Washing Facilities (Running water) Exemption Regulations, 1960. These exempt until August 1, 1961, all factories employing five workers or less from the requirement to provide running water for washing for factory workers. They also empower district inspectors to grant exemptions for factories in the circumstances specified in the regulations.

PERSONAL AND BUSINESS

Appointments

MR. S. PARKER has been appointed home sales manager of J. H. Fenner and Co., Ltd.

MR. ROBERT BRADLEY has joined Stanley Works (G.B.), Ltd., as chief planning engineer.

SIR CHARLES GOODEVE, F.R.S., is being nominated as President of the Iron and Steel Institute for 1961-62.

MR. PETER E. M. SHARP, A.C.G.I., has been appointed general manager of Westrex Company, Ltd.

MR. GORDON PATTERSON has been elected President and a director of The Yale and Towne Manufacturing Company.

MR. G. SIMS-DAVIES, M.I.Mech.E., has been appointed general manager of Hancock and Co. (Engineers), Ltd.

MR. ADAM E. KIRK, managing director of Kirk and Co. (Tubes), Ltd., has been elected a Sheriff of the City of London.

SIR RICHARD POWELL, BT., director-general of the Institute of Directors, has been appointed a director of Bovis Holdings, Ltd.

HOLMAN BROTHERS, Ltd., announces the appointment of Mr. H. S. Warwick as manager of the West African branch, with headquarters at Takoradi, Ghana.

MR. A. J. BURTON, M.I.Mech.E., is to join the headquarters staff of Birmingham Small Arms Company, Ltd., on August 1, as director of manufacturing services.

MR. W. H. EVERARD, deputy general manager of the foundry division of Edgar Allen and Co., Ltd., has been elected President of the British Electric Steel Makers' Guild.

DOWTY GROUP, Ltd., announces that Mr. Lionel Harper, managing director of Dowty Hydraulic Units, Ltd., has been appointed a director of Coventry Precision, Ltd.

ASSOCIATED ELECTRICAL INDUSTRIES, Ltd., has announced the appointment of Mr. J. A. Brooks as divisional assistant manufacturing manager, motor and control gear division.

MR. C. G. PICKETT has been appointed chief civil engineer at the civil engineering contracts section of Thyssen Shaft Sinking Company, Ltd., Coombe Road, New Malden, Surrey.

DR. J. GRIEVE has been appointed general manager of Brockhouse Castings, Ltd., in succession to Mr. W. Brunt who has retired from the position. Mr. Brunt has been appointed a director of the company.

MR. B. A. GOMM has been appointed general manager of F. Perkins (Australia) Pty., Ltd., Danderong, Australia. He has been succeeded as general manager in South Africa by Mr. A. M. B. Cross.

MR. G. C. OTTWAY has been elected president of the Council of Scientific Instrument Manufacturers' Association of Great Britain for the year 1960-61. Mr. A. W. Jones has been elected vice-president.

SAMUEL FOX AND CO., Ltd., has announced the following appointments : Mr. E. Hampshire, billet mill manager ; Mr. N. P. Bromiley, production controller ; Mr. C. Gray, assistant manager, bar and rod mill.

THE EXPORT CREDITS GUARANTEE DEPARTMENT announces that Mr. J. N. Hogg has been appointed as deputy chairman of the Department's advisory council following Sir Richard Jessel's resignation through ill health.

MR. A. G. MILNE, M.I.E.E., has been appointed Bristol manager of the South Western Electricity Board. He succeeds Mr. G. W. Richards who has retired after forty-six years' service in the electricity supply industry.

THE KEY ENGINEERING COMPANY, Ltd., has announced the following appointments : Mr. K. A. Skinner, general manager ; Mr. H. L. Harclerode, general sales manager ; Mr. F. V. Wickham, technical director ; Mr. G. H. Mortley, commercial manager.

MR. JOHN BERTRAM ADAMS has been appointed director-general of CERN until August 1, 1961. As from October 1, 1960, Mr. Adams will serve in this capacity on a part-time basis since, by agreement with the British Authorities, he will divide his time between CERN and the new laboratory for Plasma Physics at Culham, United Kingdom, of which he is director designate.

Business Announcements

MR. F. E. POMEROY has retired from the board of Nalder Brothers and Thompson, Ltd., after forty-seven years in the company's service.

HIGH DUTY ALLOYS, Ltd., has moved its Birmingham sales office to 369, City Road, Edgbaston, Birmingham, 16 (telephone, Bearwood 2344).

ALLEN WEST AND CO., Ltd., has moved its Birmingham office to Pearl Assurance House, Temple Row, Birmingham, 2 (telephone, Birmingham Central 7831).

F'AG BEARING COMPANY, Ltd., has opened a new branch office at 36, Marsel Street, Swansea, (telephone Swansea 53304), under the management of Mr. B. J. Reynolds.

WRIGHT RAIN, Ltd., announces the formation of a new company, entitled Luyben Verschueren, N.V., at Baarle Nassau, Holland, to sell its equipment in the Benelux countries.

SOLARTRON LABORATORY INSTRUMENTS, Ltd., a subsidiary of the Solartron Electronic Group, Ltd., has moved to Cox Lane, Chessington, Surrey (telephone, Lower Hook 2150).

STARTRITE ENGINEERING COMPANY, Ltd., and STARTRITE MACHINE TOOL COMPANY, Ltd., have opened new sales offices and show rooms at Darland Hall, Star Mill Lane, Chatham.

THE GENERAL ELECTRIC COMPANY, Ltd., states that the Witton Moulded Insulation Works of Birmingham has outgrown its name and is now to be known as G.E.C. Moulded Plastics Division.

JOSEPH SANKEY AND SONS, Ltd., Hadley Castle Works, Wellington, Shropshire, states that subsequent to general expansion within the Vendodi vision, its sales department has moved to 168, Regent Street, London, S.W.1 (telephone, Regent 3261).

THE DELTA METAL COMPANY, Ltd., and FOSTER BROTHERS, Ltd., announce that " Deltathene " and " Deltaplast " polythene pipes are now to be produced and marketed by a new company—Foster Brothers Plastics, Ltd., Lea Brook Tube Works, Wednesbury, Staffordshire.

PALMER-BEE COMPANY, Detroit, Michigan, U.S.A., and BROWN, LENOX AND CO., Ltd., Pontypridd, Glamorgan, South Wales, have made an agreement under which Brown, Lenox and Co., Ltd., will manufacture in this country Palmer-Bee heavy-duty conveyors and auxiliary equipment for rolling mills.

THORN ELECTRICAL INDUSTRIES, Ltd., and STANDARD TELEPHONES AND CABLES, Ltd., announce an agreement under which the " Brimar " valve and cathode ray tube division of Standard Telephones and Cables, Ltd., has been acquired by Thorn. The " special " valve division of Standard Telephones and Cables, Ltd., is not included in this agreement.

GOODYEAR TYRE AND RUBBER COMPANY, Ltd., has announced that, for the twenty-three Vickers " Vanguard " 952 aircraft to be supplied to Trans-Canada Airlines, the wheels and brakes are being manufactured by Goodyear in the U.S.A. and the tyres and anti-skid equipment by Goodyear, Great Britain, while after-sales service will be furnished by Goodyear, Canada.

WILLIAM BOBY AND COMPANY, Ltd., has made a general agreement with N.V. Bronswerk, Amersfoort, Holland, for the manufacture of Boby water treatment plant in the Benelux countries and the rest of Europe excluding Scandinavia and Italy. The agreement contains provisions for the British and Dutch firms to collaborate in the design and manufacture of all types of electrodialysis plant.

FAIREY ENGINEERING, Ltd., has been awarded by the Commonwealth Government of Australia an agency for the sale of the " Malkara " anti-tank missile throughout the world except in the United States of America. Fairey Engineering, Ltd., has also been appointed to assist in the introduction of the 400 missiles ordered for the British army ; this will involve some design work. The 5ft long, 200 lb " Malkara " is a wire-guided line-of-sight weapon.

CHASESIDE ENGINEERING COMPANY, Ltd., states that with the establishment of the headquarters of its service organisation at the premises of its parent company, British Northrop, Ltd., as from August 1, all service matters relating to Lancashire and Yorkshire will now be dealt with from Philips Road, Blackburn, Lancashire (telephone, Blackburn 4065). The Ware service depot will still be maintained, and in addition to its present activities will also cover the service and spares requirements of Norfolk, Suffolk, Hampshire, Dorset, Wiltshire, Somerset and Bristol.

Contracts

GEORGE COHEN, SONS AND CO., Ltd., has received the contract for the dismantling and disposal of the plant and buildings of the former Normanby Ironworks, Middlesborough.

PERKINS ENGINES, Ltd., has received an order from Droningborg Maskinfabrik A/S, Randers, Denmark, for 400 Four 99 diesel engines. These power units, which develop 39 b.h.p. at 3000 r.p.m., will be used in the Danish company's self-propelled combine harvesters.

POWELL DUFFRYN ENGINEERING COMPANY, Ltd., has been awarded a contract by Richard Thomas and Baldwins, Ltd., valued at approximately £300,000, for the provision at the new Spencer Works at Llanwern of site workshop and general miscellaneous engineering services.

CHEMICAL CONSTRUCTION (G.B.), Ltd., has been awarded the contract to build a 50 tons per day sulphuric acid plant and a 6 to 10 tons per hour single superphosphate plant for Adarsh Chemicals and Fertilizers, Ltd. The plant will be built at Bombay.

ASSOCIATED ELECTRICAL INDUSTRIES, Ltd., Switchgear Division, has received an order from the Central Electricity Generating Board for the switchgear associated with the experimental 380kV working of a transmission line between High Marnham and Monk Fryston. It is the first order placed by the C.E.G.B. for 380kV switchgear, and will include 380kV isolators and earth switches, substation connections and protective gear at High Marnham. The equipment will be manufactured at A.E.I. Switchgear Division's works at Willesden and Higher Openshaw, and A.E.I. Instrumentation Division's works at Trafford Park.

THE CENTRAL ELECTRICITY GENERATING BOARD has placed contracts during the past month for power stations, transmission lines and transforming stations, totalling about £4,930,000. The principal contracts include : Blyth " B " power station, booster, starting and standby boiler feed pumps for Nos. 7 and 8, 350MW turbo-generators (Sulzer Brothers (London), Ltd.) ; Uskmouth " B " power station, Mon., one 144MVA, 13·8kV/145·4kV transformer No. 3 (The General Electric Company, Ltd.) ; Brunswick Wharf power station, uprating 132kV switchgear (Associated Electrical Industries, Ltd.) ; Kirkby 132kV substation, 132kV outdoor switchgear (Associated Electrical Industries, Ltd.) ; High Marnham substation, one 400MVA, 380kV/275kV, auto-transformer (the English Electric Company, Ltd.) ; Monk Fryston substation, one 400MVA, 380kV/275kV, auto-transformer (Ferranti, Ltd.) ; Corby substation, two 180MVA, 275kV/132kV transformers (the English Electric Company, Ltd.) ; Bustleholm substation, two 180MVA, 275kV/132kV transformers (The General Electric Company, Ltd.) ; Brinsworth substation, 275kV, 7500MVA switchgear (Associated Electrical Industries, Ltd.), 275kV overhead lines (British Insulated Callender's Cables, Ltd.) ; Nechells substation, 132kV, 3500MVA switchgear (The General Electric Company, Ltd.) ; Rugeley-Whitfield, 132kV overhead line (Associated Electrical Industries, Ltd.) Ironbridge-Oswestry, 132kV overhead line (Balfour Beatty and Co., Ltd.).

Miscellanea

FLEXIBLE HYDRAULIC HOSE.—Hydraulic hose for vehicle brake systems is now being reinforced with I.C.I. " Terylene " polyester fibre in all Lockheed and Girling installations. " Terylene " was chosen for the ability to contain pressure with very little expansion, but has also effected an increase in strength ; previous Lockheed hose to meet the S.A.E. requirement of 5000 lb per square inch was tested to 8000 lb per square inch, whereas the new hose is tested to 12,900 lb per square inch.

HEAT EXCHANGE UNIT.—A heat exchanger capable of removing up to 10,000 B.Th.U. per hour from fluids at pressures up to 2000 lb per square inch has been evolved by Crane Packing, Ltd., Slough, Bucks, primarily for inclusion in cooling systems for mechanical shaft seals. Flow rates for product and coolant (water) range up to 120 g.p.h., and the " working temperature " up to 180 deg. Fah. The " Heat Dissipater " is entirely of stainless steel, except for the connections in contact with water, which are of cadmium plated mild steel.

CONTINENTAL AFFAIRS

by Our Continental Editor

Moselle Canal Progress

No. I

The Moselle Treaty signed in October, 1956, by France, the German Federal Republic, and Luxembourg, provides for making the river navigable for 1500-tonne vessels between Thionville and the confluence with the Rhine at Koblenz. It is hoped to have the canalisation in use by 1963, initially with a capacity of 10,000,000 tonnes per annum. Some 800 million kWh of electricity will also be generated in power stations making use of tubular Kaplan turbines ("bulb" turbines). The navigation is to be extended to Metz by widening the existing Iron Ore Canal to carry ships of 1500 tonnes. On its completion, the Moselle Canal is to be operated as an international waterway under a similar règime to the Rhine. The following article describes the project and some of the work now being carried out.

FROM its origin on the Col de Bussang (735m sea level) in the Vosges mountains, to its confluence with the Rhine at Koblenz (at 59m sea level), the Moselle has a length of 520 km of which 278 km are in France, 36 km form the frontier between Germany and Luxembourg, and the remaining 206 km are in German territory: of the total catchment area of 28,000 square kilometres, about 11,500 square kilometres are in France, the principal tributaries being the Meurthe and Seille on the right bank and the Madon and Orne on the left. Between the Franco–German frontier at Apach and the city of Trier (Trèves) about 45 km downstream, the rivers Sûre (Sauer) on the left bank, and Saar (Sarre) on the right, contribute the catchment from a further 12,500 square kilometres. Below Trier lies the remainder of the catchment area, 4000 km without any major tributaries.

The Moselle is characterised by the wide variation in its water burden, and the rapid rise of of its flood waters. In times of prolonged drought, as in 1949, the flow rate may fall to as little as 10 cumecs, while on the other hand during major floods, as in December, 1947, a flow of 3000 cumecs was observed at the mouth of the Sûre, and as much as 4300 cumecs at the confluence of the Saar. The river has been known to rise at the rate of 20cm per hour.

Taking the confluence of the Sûre as point of reference, the average minimum flow rate over the years 1927–57 amounted to 29 cumecs, while the median rate was 85 cumecs.

Shipping on the Moselle flourished until the nineteenth century, but later declined as the river was not suitable for the larger boats which alone could have competed with the railway. To this day, however, shipping traditions are maintained in riparian towns such as Wasserbillig in Luxembourg many of whose citizens practise their trade on the Rhine and other inland waterways. Regulation work carried out between 1838 and 1890 was confined to the construction of groins and dykes and did not concern itself with navigation.

With the rise of the Lorraine iron and steel industry, on the basis of the Minette ores, interest was aroused in cheap coal of good coking quality. Such coal is obtainable from the Ruhr basin, from where transport by water over the Rhine and Moselle constitutes the most direct and cheapest route. The question of whether the Moselle navigation should be built was therefore for many years a matter of contention, principally between the steel interests of Lorraine and their competitors on the Rhine and Ruhr. Arguments against the canal put forward by the German side have been that it would be uneconomic for the volume of traffic in question, and that in any case the railway was providing an efficient and equitable service. To this, the Lorraine steel industry was able to point out that as recently as 1940 when the province was in German hands the canalisation scheme was regarded favourably by the German Government which made a beginning by constructing a weir and lock at Koblenz. As regards the cost of rail transportation, although there was no direct tariff discrimination against France, a differential treatment was practised by allowing important rebates to the German works. It was maintained in favour of the canal scheme that so far from being an economic liability it would pay for itself owing to the existing and potential traffic demand. For the period immediately following the opening, French estimates have put the total annual tonnage demand at approximately 10,000,000 tonnes, being made up as follows :

Upstream traffic :	
Coke	2,500,000 tonnes
Coking coal	1,100,000 tonnes
Overseas ores	450,000 tonnes
Scrap	100,000 tonnes
Miscellaneous	550,000 tonnes
Total	4,700,000 tonnes
Downstream traffic :	
Steel products	1,800,000 tonnes
Wheat	300,000 tonnes
Timber	450,000 tonnes
Cement, slag, &c.	700,000 tonnes
Total	3,250,000 tonnes
Local traffic between Trier and Koblenz	1,000,000 tonnes
Total traffic to and from Luxembourg	1,000,000 tonnes

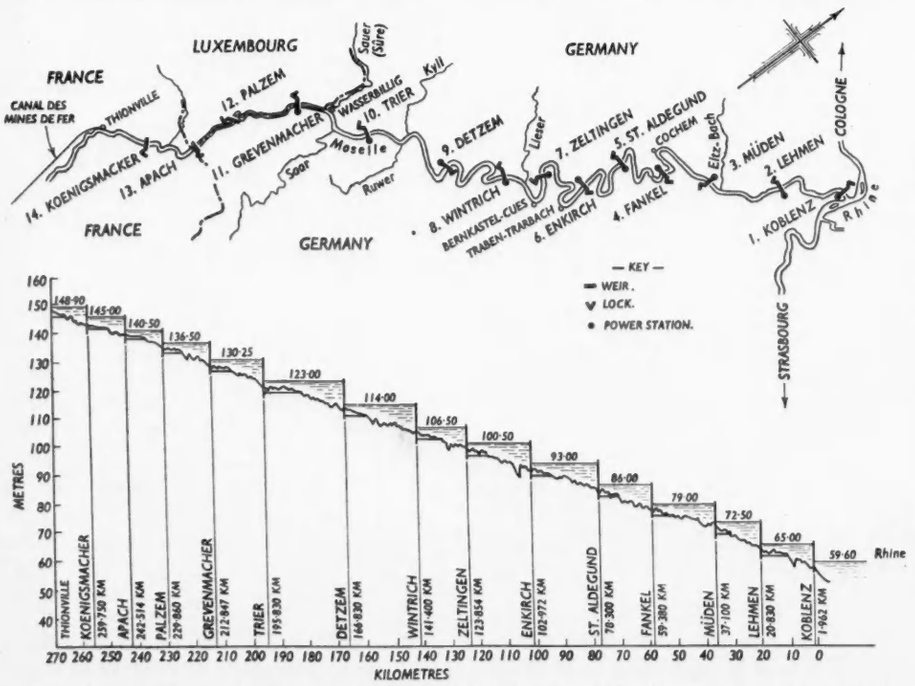


Fig. 1—General scheme of Moselle navigation. In addition to the existing weir and lock at Koblenz, thirteen further stages and a second lock at Koblenz are scheduled for construction by 1963, to make Thionville accessible to vessels of 1500 tonnes. Power stations to generate 800 million kWh annually are also being built

Moselle Treaty

Following the setting-up of the European Coal and Steel Community in 1952, negotiations for the Moselle Canal were successfully concluded with the signing of a treaty at Luxembourg on October 27, 1956, between the French Republic, the German Federal Republic, and the Grand Duchy of Luxembourg. Some hard bargaining had preceded the agreement ; an important concession by France concerned the Rhine Canal (Grand Canal d'Alsace). This canal,* which was to have extended from Kembs near Basle to Strasbourg, now was to end halfway at Vogelgrün. The remaining stages were to be river stages, with locks and power plants constructed in loop canals. Although more expensive and less favourable to maintenance and navigation, the modified scheme preserved German access to this part of the Rhine, and by keeping the existing river bed filled prevented any danger to the land which might arise from a lowering of the water table.

The Moselle Treaty stipulated the construction at an early date of a waterway on the Moselle connecting Thionville and Koblenz and suitable for 1500-tonne vessels. For the overall financial and technical control of the enterprise there was to be established within one month of the treaty coming into force the "International Moselle Company," a limited company under German law (G.m.b.H.) and with a seat in Trier. Its capital of DM.102 million was contributed by France and Germany in equal shares of DM. 50,000,000 and the rest by Luxembourg. The

* THE ENGINEER, April 30, 1957, page 322.

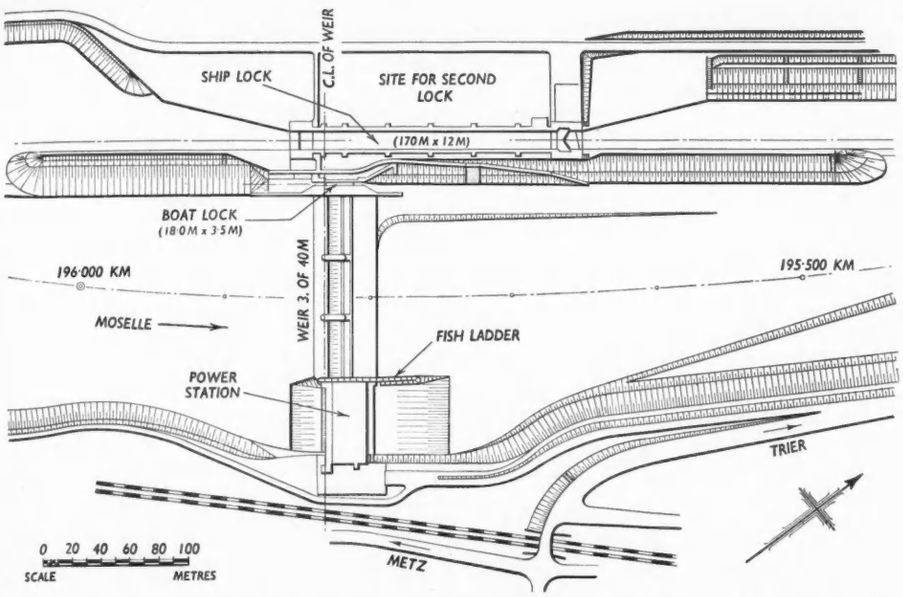


Fig. 2—Nearing completion is the stage at Trier-Feyen, which comprises a barrage with three 40m wide sector gates, a shipping lock of standard size (170m long by 12m wide), a boat lock and a power station. A second lock, 20m wide, can be built at some later date

total cost of the work had been estimated in August, 1955, as DM.370 million, of which Germany was to contribute DM.120 million, France DM.248 million, and Luxembourg DM.2,000,000, any excess sums to be covered by Germany and France in the ratio of 120 : 250. A further contribution *à fonds perdus* of DM. 70,000,000 by Germany and DM.10,000,000 by France was agreed upon for purposes other than the navigation.

On completion, the canal will be taken over and operated by an international commission under a régime similar to that on the Rhine. The Moselle is to be open to international shipping, the traffic revenue being devoted to operation, maintenance, and repayment of the capital, in that order. The system of charges is laid down in detail in the Treaty. Freight and passenger rates are to correspond to the average prevailing on the rivers Main and Neckar and will remain linked to them. The tariff structure is to be based on the German Transport Ministry's classification of goods, initial rates varying from 0·9 pfennig per tonne-kilometre for Class I to 0·275 pfennig per tonne-kilometre for Class VI. Special reduced rates were laid down for fourteen items, including, in particular, coal, ores, scrap, and slag (0·20 pfennig per tonne-kilometre each), pit props (0·175 pfennig per tonne-kilometre), and cement (0·285 pfennig per tonne-kilometre).

General Scheme

As laid down in the Treaty, the construction programme comprises thirteen stages between Koblenz at river kilometre 0 and Thionville (Diedenhofen) at river kilometre 270·781, of which nine are downstream of the mouth of the Sûre at Lehmen, Müden, Fankel, St. Aldegund, Enkirch, Zeltingen, Wintrich, Detzem, and Trier. Four are above the confluence of the Sûre, at Grevenmacher and Palzem on the German–Luxembourg frontier, and Apach and Königsmacher in France.

Our illustration (Fig. 1) shows the scheme. The work involves the construction of weirs and locks, a shipping channel and ports. It is being carried out under the supervision and detailed control of the Moselle Company by the national river boards of the region, which have engaged a large number of private contractors. Power stations are being built in conjunction with the various stages in Germany and on the German–Luxembourg border—there will be none in France—by a separate undertaking, the Moselle Power Company. The Canal des Mines de Fer de la Moselle (CAMIFEMO) between Metz and Thionville, completed in 1932 to carry 300-tonne iron ore barges, is to be enlarged by France to enable vessels of 1500 tonnes to reach Metz from the Rhine.

Navigation Works

The canal is to remain navigable for rates of flow ranging from the minimum up to 650 or 700 cumecs. In order to preserve the scenery of the Moselle valley as much as possible, all structures had to be built so as to project as little as possible above the water. Under extreme flooding the whole area, including weirs, locks and power stations, will be submerged, an eventuality which the design had to allow for.

Barrages.—In general, each stage is to have three sector gates, each 40m wide, but above the Sûre confluence, at Grevenmacher and at Palzem, only two gates of 40m width are to be used. Of the two French stages, Apach will have one lever weir and two sector weirs, each 27·5m wide, while Königsmacher is to be equipped with four openings of 27·5m each, of which two will have lever gates, and two, sector gates.

Locks.—The standard ship locks are to have a clear length of 170m, and a clear width between fenders of 12m. The minimum depth of water is to be 3·5m, so as to allow for a future deepening of the channel from 2·9m to this figure. A second lock to the already existing one is to be constructed at Koblenz, and provision is to be made at the site and in the dimensioning of the crown and tail bays to permit the addition of a second series of locks of the same length but of 20m width for pusher traffic.

For boats and pleasure craft, small locks 18m long by 3·5m wide are being provided ; these have a minimum depth of 1·5m.

(To be continued.)

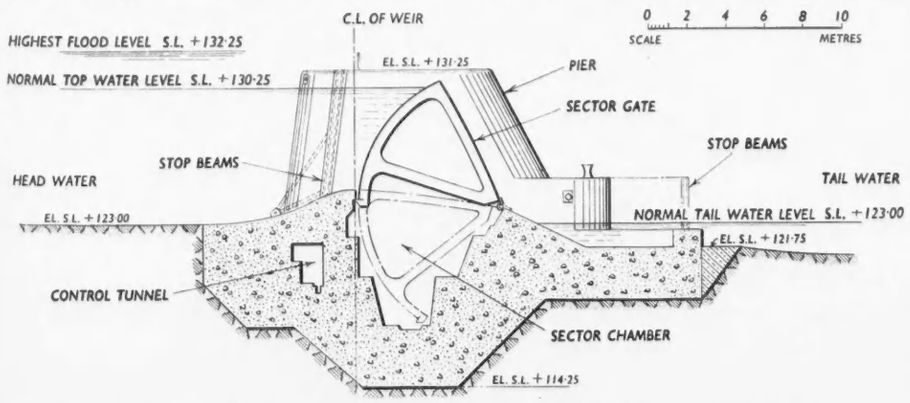


Fig. 3—Sectional elevation of weir at Trier, for a head of 7·25m. Floating sector gates of this design have been specially developed for the Moselle where superstructures had to be kept to a minimum in order to preserve the scenery

Instruments and Measurements Conference and Exhibition

The Fifth International Instruments and Measurements Conference and Exhibition, organised by the Royal Swedish Academy of Engineering Sciences and the Swedish Association of Technical Physicists, will take place from September 13 to 16 at the Royal Institute of Technology, Stockholm. The United Kingdom Atomic Energy Authority and the Nuclear Energy Trade Associations' Conference are co-ordinating a large British contribution of scientific papers, scientific exhibits and industrial and commercial exhibits.

Twenty-six papers on nuclear subjects—fourteen from U.K.A.E.A., one from Department of Scientific and Industrial Research and eleven from industry—have been accepted from the United Kingdom. A scientific exhibition will also be held in the Royal Institute of Technology, from September 12 to 16, while a commercial instruments and measurements exhibition will be held in the Osterman Marble Halls from September 10 to 17. About one-third of the total space will be occupied by a self-contained British Section, with a total area of 6000 square feet.

375MVA High-Voltage Transformer

A.S.E.A., Västerås, has received from the Swedish State Power Board an order for a 400kV, three-phase transformer, which is to have a rating of 350,000kVA in the initial stage of operation. Later on, the rating will be increased to 375,000kVA. This transformer unit, it is stated, will be the largest ever manufactured by the company and it will constitute a world record for the high voltage in question. The increase in transformer ratings leads to a better economy, which in the attempt to reduce the costs of power transmission constitutes an important step. It is often the transport facilities which limit the size of a transformer: in the present case a new transport truck will be required. The Swedish State Railways have recently ordered such a truck, which will have a load capacity of 260 tons. However, the total capacity of this truck will not be utilised, since during the last part of the journey the transformer will have to travel by road, where the maximum load will be limited to 225 tons. When erected on its site, the transformer will have a total weight of about 300 tons.

Second Ilmac Congress and Exhibition

Following the great success of the first ILMAC (International Congress and Exhibition of Laboratory, Measurement and Automation Techniques in Chemistry) which took place in November, 1959, in Basle, the organising committee have decided unanimously to repeat that event. The second ILMAC will be held from October 15 to 20, 1962, in the buildings of the Swiss Industries Fair in Basle.

THE AMERICAN SCENE

by Our American Editor

Compact Cars

The present confusion among motor car makers in Detroit is understandable. In the first quarter of this year, for example, the American public rushed to buy a record number of expensive Cadillacs. At the same time, it tumbled over itself in quest of such money-saving " compact " cars as the " Falcon," the " Valiant," the " Corvair " and the " Comet," as well as the " Rambler " and the " Lark." These contrary trends created a " squeeze on the middle," which hurt such makes as Chrysler's DeSoto, General Motors' Buick and Ford's Mercury, and cut into sales even of conventional Fords and Plymouths. As the scramble for competitive position intensifies, several uncertainties now hang over the Motor City like a pall of exhaust. The fast-selling compact cars, it must be remembered, require no such " money-saving " optional equipment as power steering and power brakes. Thus, even a 6,500,000 car year, if it could be achieved, would not mean what it used to. To date, in terms of production and sales, things are not too bad, although a 6,200,000 car year seems about the best the industry can hope for. Two million automobiles were produced in the first quarter of 1960, and 1,000,000 were still in the hands of dealers on April 1. The projection for the second quarter called for an output of 1,700,000 cars, with compact cars rising from 23 per cent of the total to 31 per cent.

Many an intellectual, contemptuous of tail fins and big car display generally, has scoffed at Detroit for not getting down to utility cars until the 1960 model years. The argument is that if American Motors could produce the " Rambler American " in 1958 as the answer to the imported Volkswagens and Renaults, the rest of the motor-car makers at least might have joined the parade in 1959. However, American Motors, as the rest of Detroit sees it, had nothing to lose. Moreover, by luck or foresight, it had kept its old 1954 " Rambler American " dies—which, as the compact idea took hold, could be put back to work Chrysler, which had made a stubby Plymouth in the early 'fifties, had no such good fortune ; its old dies long since had gone to the scrap yard. To do Detroit belated justice, it actually got the compact car idea in 1958, when foreign car imports approached the 500,000 a year mark. Throughout that year and part of 1959, however, it had to keep its plans under wraps, lest it spoil the market for the cars it already was making. Meanwhile, General Motors' Chevrolet division, Ford and Chrysler-Plymouth were all busily—and secretly—at work on small models. As the critics continued to poke fun at tail fins and as Mr. George Romney of American Motors kept making speeches about the " gas-guzzling dinosaurs," they had to grin and bear it. But when October of 1959 came they were ready.

In meeting the challenge of a changed world, the Big Three have followed divergent philosophies. Ford and Chrysler, preening themselves on the success of their compacts, now speak of the General Motors' record with the " Corvair " as a defeat. As of April 1, General Motors had produced only 95,275 of these little cars, as compared to Ford's 129,122 " Falcons." Chrysler, with 72,811 " Valiants," had yet to match the total " Corvair " production, but at the end of March the " Valiant " was doing considerably better, week by week, than the " Corvair." American Motors, which lumps all of its cars in the compact category, also was ahead of the " Corvair " on a weekly output basis, by more than two-to-one. However, Chevrolet is not worrying about bringing up the rear of the compact race. In the firm's opinion, the " Corvair " was not designed to " feed off the regular Chevrolet lines." It was made to look like a small car, with distinctive features of its own, such as an air-cooled aluminium engine in the rear, no hump in the floor, room for six-at-a-squeeze, and a back seat that folds down to provide a platform for cartons from the shopping centre. In brief, the " Corvair " was intended for the second- and third-car customers, and made easy to handle for women drivers, but designed not to reduce the average buyer's interest in full-size cars. Moreover, because it really is separated from the rest of the Chevrolet line, there will be no temptation to build it up into a " de luxe " car, which is what happened to the cheaper Chevrolets in the early 'fifties. Since the " Corvair " was designed to seem like a sturdier, roomier Volkswagen (all this, and optional automatic transmission, too), it permits the Chevrolet dealer to say, " Yes we have a good compact. But just think for only a few dollars more, you can have this," pointing to a " Biscayne," or even a " Bel Air " model Chevrolet. To date, this pitch seems to have been successful : in a seventy-day period, although " Falcons " outraced " Corvairs " by almost 40,000, full-sized Chevrolets outsold Fords by over 91,000. The Chevrolet division's grand total for the period, then, is 51,556 better than Ford's—a big difference, considering that the two often have run neck-and-neck. Chevrolet thinks this record particularly significant because its conventional 1960 cars are face-lifted models, while the Fords are not. To keep the big Chevrolets selling, some dealers have been rationed on " Corvairs "—only one for every four or five larger cars. The firm reports that the " Corvair " has done particularly well in areas like Los Angeles, where European small-car imports have been popular, and deduces that its compact has been cutting into this market. Inasmuch as foreign sales have been increasing year by year, this is additional cause for the Chevrolet optimism.

The Ford Motor Company, for its part, does not believe that the " Falcon," which looks like a light-weight member of the regular Ford family, has been hurting its regular lines. True, output of the conventional cars has lagged since the beginning of the year. But the company attributes this to the fact that it was turning out 1960 models late in 1959, when Chevrolet lacked steel. With its own River Rouge Works steel available throughout the steel strike, Ford already had stocked its dealers when others still were crying for cars. The augmented Chevrolet sales of recent months, so the argument runs, represent merely a catching up to the business Ford had done in the last quarter of 1959. Meanwhile, to justify their own optimism, the Ford spokesmen point to the big jump in Ford production that occurred during the last week in March. It is of interest to note that " Falcon " buyers have been calling for fewer " extras " than those who buy big Fords. According to recent reports, 43 per cent of the former have asked for automatic transmissions, as against 76 per cent on the Ford ; the demand for heaters has been 86 per cent as against 92 per cent ; car radios, 50 per cent as against 76 per cent ; white-wall tyres, 41 per cent as against 58 per cent. All of this, other things being equal, means less money for the dealer and for the company. The success of the " big " compact, the Ford " Comet," however, suggests that " other things " may not be equal for long. For this newcomer, which attained manufacturing volume only at the end of March, got off to a brilliant start. If the " Comet " should achieve a success similar to that of Chrysler's Dodge " Dart," it could give added richness to the Ford product mix.

With the " Falcon," Ford's idea was to eliminate 1500 lb of the weight of a standard Ford, to get fuel economy. Averaging out the tests made by various magazines, " Falcon " has been getting 25·64 miles to the gallon, as compared to the " Rambler American's " 23, the " Corvair's " 22·1 and the " Valiant's " 20·5. In a more recent comprehensive road test, the " Rambler " won, and both the " Valiant " and the " Corvair " did considerably better. In price, the " Falcon " beats the rest of the field—it sells for 72 dollars less than the " Corvair " and for 78 dollars less than the " Valiant." With three works devoted solely to the " Falcon," and the Lorain, Ohio works split between " Falcon's " and " Comets," Ford is creeping up on American Motors in the race for compact supremacy. If the popularity of the " Falcon " is to be at the permanent expense of the large Ford cars, this could be a dubious victory. But the company takes heart from two statistics : over 50 per cent of the cars traded in for " Falcons " are non-Ford products, thus representing " conquest sales," and 25 per cent of " Falcon " sales are " clean deals " involving no trade-in, suggesting that the buyer may be keeping his Ford or " Mercury." Ford calculates that of the new " Falcon " buyers, some 35 per cent in other years might have bought a used car. This portends a continuing softness in the used car market and might make sales of expensive cars more difficult. But regardless of what may happen to the regular Ford line, the company is committed to the smaller car. It is now " studying the

market " for a four-cylinder, four-passenger midget, tentatively called the " Hummingbird," to compete with Volkswagens, Rambler " Metropolitans," and Renaults.

Of the Big Three, Chrysler seems likely to make the most dramatic turn from 1959, when it had a net loss of over 5,000,000 dollars. Its " Valiant," which only now is being produced in quantity, is a heavy compact, but sturdy. It can take hard bumps, it has a powerful six-cylinder engine, and it has plenty of baggage room. Toward the end of the winter, it started outstripping Plymouth in production, which might indicate that it was " feeding off " that old stand-by, even as the " Falcon " supposedly has been feeding off the Ford. To challenge this conclusion, Chrysler offers its experience with the phenomenally successful Dodge " Dart." This newcomer stepped up first-quarter production at Dodge to 113,241, from 44,043 in the first quarter of 1959. Plymouth production, meanwhile, declined from 102,419 to 91,430. Adding " Darts " and Plymouths, one can see that Chrysler in 1960 has gained rather than lost in what used to be the " low-price " field. Thus it hardly can be said that the " Valiant " is feeding off the cars just above it ; indeed, one out of three " Valiants " has been sold without a trade-in. This fact would seem to imply that it either is expanding the total market or attracting second- and third-car buyers who formerly might have gone to foreign sources or the used car lots. The V-200, the more expensive " Valiant," has been outselling the V-100 by 65 per cent to 35 per cent, representing a notable inversion within the general trend toward the less expensive cars. Since Chrysler, with its renovated production lines, is more efficient than it has been in some years, and since it is improving its cost-control generally, there has been speculation that its break-even point may now be 13 per cent of the market in a 6,500,000 car year, as compared to the traditional 15 per cent. However, the heavy costs of the premium steel which the company still was buying in early 1960 must be reckoned as an immediate, if non-recurring, offset to its improved efficiency.

So much, then, for the outlook for the various makes and models. Now what about Detroit's overall prospects for the year ? At the end of 1959, when everybody was talking of the " Sizzling Sixties," starting with a bang right after New Year's Eve, the motor car firms were caught up in the general bullishness. The manufacturers were confident that 7,000,000 cars could be marketed in the year, 6,500,000 of them U.S.-made. The probability that compact cars would corner 25 per cent of the 6,500,000 market did not unduly disturb Detroit. But after a long, cold winter, ending with the fierce nation-wide snows of March, the 6,500,000 market seemed to be fading. Moreover, in what was left of it, the " profit squeeze " was on. No matter how it tries to look on the bright side, Detroit cannot expect to make more money out of an equal or smaller number of cars that includes a growing number of compacts. Nor has the industry ceased trying to outguess the future. Where the automobile used to be the American status symbol, it now has become merely one of many. Though the assistants who write the speeches for the automobile industry's executives still deal in such concepts as " disposable income " and " rate of car scrappage," which supposedly prove that the American society is an affluent one, Detroit now must realise that this society has a good many responsibilities to match its money. On the one hand, the affluent society has children in ever-growing numbers; on the other, it has taxes. With the pinch on at both ends, the after-tax affluence may have to cover college educations, orthodontist bills, a ski trip to Sun Valley, and a new outboard motor boat for summer at the lake. Since virtually everything has become a status symbol the whole concept has become meaningless, and the automobile suddenly has reverted to what it used to be : a means of transportation. Naturally, with the number of three-car families growing, transportation must continue to come relatively cheap. Furthermore, as cars grow smaller, the manufacturers are faced with the continuing costs of technological experiment. The forthcoming " compact " Buicks, Oldsmobiles and Pontiacs, made on the unitised principle to provide legroom, will require a complete change in manufacturing method. The need to get the leg-cramping " hump " out of the small car, which " Corvair " has met by putting the engine in the rear, means that money must be spent on experiments with front-wheel drives, or with aluminium engines light enough to be placed over the rear axle without disrupting the balance of the car. Whatever choices the companies may make on engine placement, or " hump " removal, or tuning to get " big-car feel " on a small-car wheelbase, the demand for capital for experiment and for new production equipment is bound to have some impact on profits. Then, too, the chromium-plated years in which the manufacturers could be sure of their markets have gone, possibly never to return. The names of " Rambler," " Lark," " Falcon," " Valiant," " Corvair " and " Comet," which are reponses to a crowded high-tax world, are all relatively new in the lists—and five years from now there may be as many more.

Transfer Machines for High-precision Finishing Operations

WHILE it is still unusual to design a transfer machine for finishing operations, a new " Transfer-matic " has now been designed and built by the Cross Company, of Detroit, Michigan, which successfully combines high-precision finishing operations for automotive transmission cases with the production economy of automation. In its operation, some bore sizes are held to tolerances of plus or minus 0·00035in and the locations of three holes are held within plus or minus 0·001in, each to both others. Twin milling operations establish an over-all part length within plus or minus 0·0039in. The surface finish specifications are 56 to 110 micro-inches, r.m.s., for all machining operations. The five-station precision machine has a production rate of 140 parts per hour at 100 per cent efficiency. The cast iron transmission cases are delivered to the transfer machine rough-machined, but the requirements of the workpiece have been no help in the design of the machine. The locating holes are in lugs on top of the case, as far away from the points of clamping and high accuracy as it is possible to get. In fact, these lugs are removed from the part before it is used.

To ensure the required accuracy, the machine has been designed for high rigidity at each of its four machining stations. The centre bases and wings at each station have been made integral to ensure proper alignment. Each base has been mounted on a separate foundation so that vibrations cannot be transmitted from station to station. The workpieces are clamped, two at a time with the cover faces down, in precision pallet-fixtures. These pallets are accurately located and positively clamped in successive machining stations. In the machining stations, the pallet is located in the horizontal plane by six buttons. Provision has been made for blowing air over these buttons during each transfer so that chips cannot lodge on them. The pallets are located both longitudinally and transversely by the action of a wedge-and-slot locator after the lift-and-carry transfer bar has moved the pallet to an approximate location. The precise location is achieved by pushing the accurately located one-sided wedge into a slot in the pallet with a hydraulic cylinder. The reference plane is the flat side of the slot in each of the pallets.

As the wedge moves the pallet into its longitudinal position, it also pushes the pallet transversely against two stop buttons. These buttons

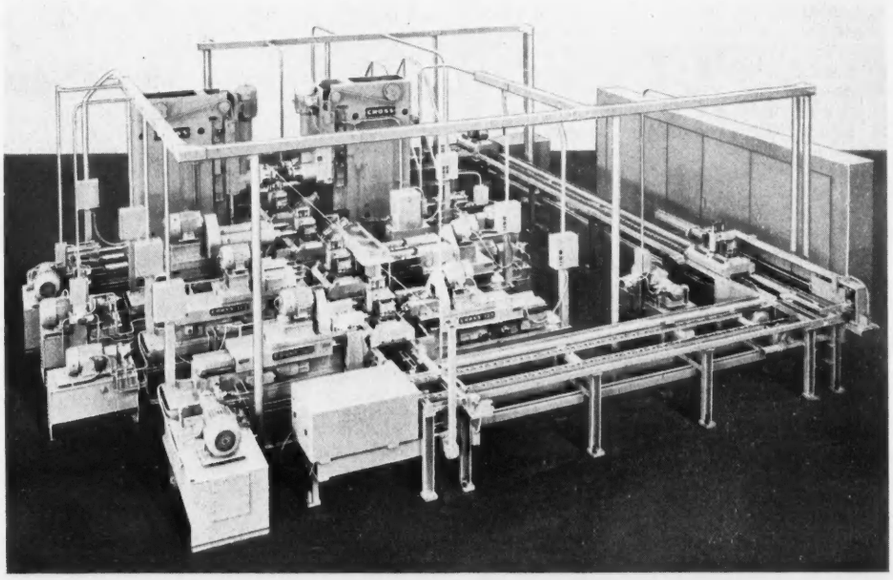


Fig. 1—Overall view of " Transfer-matic " machine for transmission cases, with one milling station and three boring stations

THE AMERICAN SCENE *(Continued)*

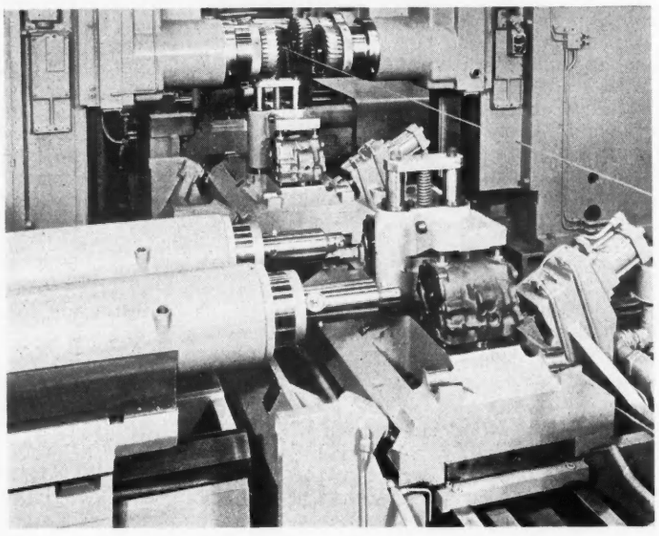


Fig. 2—Close-up view of pallet fixtures which rest on six buttons and are forced transversely against two angular stops. Hydraulic cylinders actuate the clamping and locating wedges

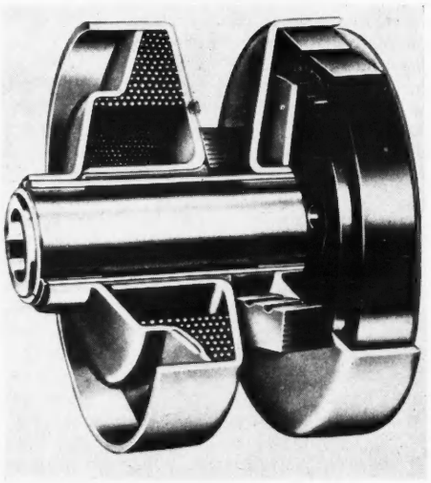
are set with their faces 30 deg. from the vertical, matching locating surfaces on the pallet and causing the pallet to be wedged downward. It is the combination of these forces that clamps the pallet. Passages, which carry low-pressure compressed air, lead to orifices in both the straight and the inclined faces of the wedge, and the locating faces of the two transverse stop buttons. All these orifices are open to the atmosphere until the pallet is accurately located and correctly clamped. Then, pressure build-up in the air lines activates an air-operated limit switch and initiates the machining cycle.

An accurate location of the pallets is necessary because not all holes whose locations are tied together by close tolerances could be bored with clustered spindles in one station. Because of their proximity on the workpiece, each of the three holes tied together by the closest location tolerances is finished in a different station. Each of the eight precision boring spindles is separately mounted on its slide so that each can be adjusted individually. The boring bars are made of a solid, heavy metal to damp vibrations, and those for the largest holes finish both end holes from the same side of the machine. One of these holes is larger than the other so that the boring bar can reach through. The boring bars for these holes each have four micro-adjustable boring cartridges—one for semi-finish cuts and one for finish cuts on each hole. The boring bars for the smaller holes have the same construction and the same individual adjustment for each cutting bit. Two holes are finished with a single straight-fluted reamer.

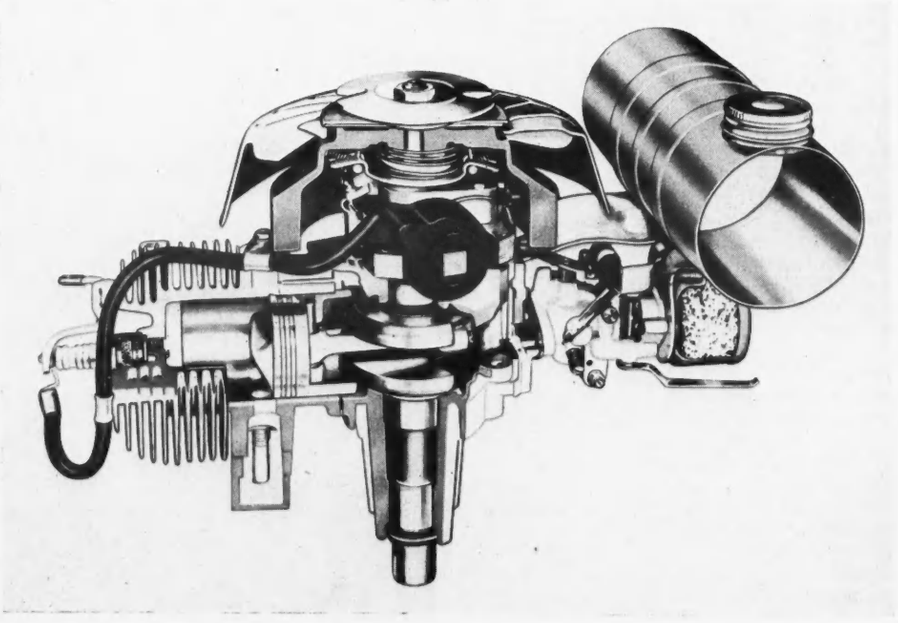
Engines for Europe

The immense and expanding demand for small power units within the European Common Market is being met, at least in part, by the manufacture of engines of United States origin by Aspera Motors of Turin under licences that allow the engines to be sold outside the E.C.M., even in U.S.A.—the agents in U.K. are Mackay Industrial Equipment, Ltd., Feltham, Middlesex. These engines are, by European standards, extremely ambitious, being either two-strokes with automatic inlet valves or four-strokes with side valves, diaphragm carburettors being used in all cases, and speeds up to 4000 r.p.m. being available with light alloy connecting-rods running on fully counterbalanced cast shafts. The high-speed engines run on the two-stroke cycle, the 77 c.c. unit up to 6000 r.p.m. and the 130·8 c.c. unit up to 5500 r.p.m.; this larger engine gives 6·00 h.p. and weighs only 13¾ lb. All those engines which are not roller bearing throughout are provided with mechanical maximum speed governors. The details of the construction are also noteworthy ; the main components are die cast in aluminium, around the cylinder liner and, in the case of the four-stroke, a sintered ferrous valve seat insert ; cylinder heads are secured by screws ; and the four-strokes have visible oil level indicators. The hand starters available include an impulse starter, wound up gradually and then released, with which even a girl can start a four-stroke single. The engines were developed by the Lauson Engine Division of Tecumseh Products Company, New Holstein, Wis.

The engines are available complete with transmissions. These may take the form either of a speed-sensitive torque-sensitive automatic clutch, or of such a clutch backed up by an automatically varying belt drive. We illustrate the drive end of the latter, " Dry-Draulic," device. The engine drives the symmetrical cam within the shoes of the clutch ; this cam acts to load the shoes, so that once centrifugal force has overcome the garter spring and engaged the shoes, the clutch drives without slipping down to relatively low speeds. The steplessly variable belt drive is of a conventional form with a spring-loaded compensating pulley ; the effective diameter of the driving pulley is altered by the centrifugal force on the numerous small steel balls in the pulley acting against the compensating pulley and the belt tension due to speed. The ratio varies from a reduction of 2·6 to an increase of 4·35 ; the drive pulley can have an additional constant size pulley outside the sliding pulley. These transmissions were developed by Hoover Transmission Company, Inc., Williamstown, Mass.



Hoover " Dry-Draulic " transmission in reduction configuration



Section through a plain-bearing, two-stroke single, with a light alloy connecting-rod running direct on the cast crankshaft ; this and all other Lauson engines without roller big-end bearings are protected by mechanical governors

BRITISH PATENT SPECIFICATIONS

The dates printed are those of application and publication on completion. Copies of specifications may be obtained at the Patent Office Sales Branch, Southampton Buildings, Chancery Lane, W.C.2, 3s. 6d. each

CYLINDERS

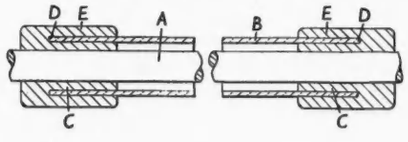
839,525. February 5, 1959.—CYLINDER BARREL, Ruston and Hornsby, Ltd., Sheaf Iron Works, Waterside South, Lincoln. (*Inventor: Richard James Dain.*)

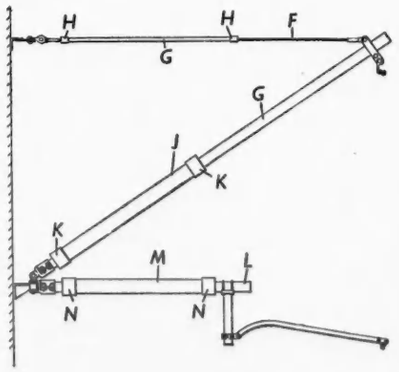
This invention relates to cylinder barrels of reciprocating engines and machines; and more particularly to barrels of aluminium not provided with conventional cylinder liners. The aluminium cylinder barrel has its inner wall working surface of sprayed iron. The surface of the bore may first be prepared by shot or sand blasting or rough machining and a coating of molybdenum applied to act as a bond for the sprayed iron. The depth of the coating of molybdenum may be, for example, between 0·001in and 0·006in, whilst that of the sprayed iron may be between 0·005in and 0·020in. Instead of iron, a nickel-chrome alloy may be used as the interior surfacing—*June* 29, 1690.

RAILWAY ELECTRIFICATION

841,090. December 3, 1957.—OVERHEAD ELECTRIFICATION SYSTEMS FOR RAILWAYS, British Insulated Callender's Cables, Ltd., Norfolk House, Norfolk Street, London, W.C.2. (*Inventor : Arthur George Sweetland.*)

This invention relates to overhead electric traction systems in which the construction of cantilevers for supporting the catenary is such that the strut, the tie member and at least one part (the inner part) of the registration arm each comprise a rod or tube fabricated from resin-bonded glass fibre. A modified form of this cantilever structure is provided which permits the structure to be used on 25kV systems with little risk of tracking. In accordance with the invention at least a part of the length of each of the three members of the cantilever structure that are made of resin-bonded glass fibre is enclosed in a tube of vitreous or ceramic material and each end of this tube is sealed to the resin-bonded glass fibre member by a flexible bush of elastomeric material. As an example, the resin-bonded glass fibre member *A*





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shown in the upper drawing has a part of its length enclosed in a protective tube *B* of ceramic material. The tube is sealed at each end to the member *A* by a flexible bush *C* of " Neoprene," the bore of which is a tight fit over the member. The outer end of each of the " Neoprene " bushes has a circumferentially extending surface *D* which serves as an abutment to locate the tube *B* endwise in one direction relative to the member *A*. A circumferential wall *E* projecting from the surface *D* surrounds the end of the tube *B*, protecting the resin-bonded glass fibre member on which the bush is fitted. Referring to the cantilever structure shown in the lower drawing, part of the length of the tie rod *F* is enclosed in a protective tube *G* of ceramic material which is sealed at each end to the tie rod by a " Neoprene " bush *H*. To lessen the risk of surface contamination by steam traffic the tube *F* is preferably applied to the mast end of the tie rod. A protective tube *J* of ceramic material encloses a lower part of the length of the inclined strut *G* and is sealed at each end to the strut by a " Neoprene " bush *K*. The major part of the length of the inner registration arm *L* is enclosed in a protective tube *M* of ceramic material which is sealed at each end to the inner registration arm by a " Neoprene " bush *N*. By the method indicated, the enclosed member or the enclosed part thereof is kept dry and free from pollution. As a result tracking is eliminated. The length of each member to be so protected is dependent on the operating voltage of the electrical system on which the cantilever structure is intended to be used. By way of example it is mentioned that present indications are that for a 25kV a.c. system, each resin-bonded glass fibre member should be fitted with a vitreous or ceramic tube having a length of about 5ft or with a number of such tubes of the same aggregate length.—*July* 13, 1960.

ELECTRIC LIGHTING

840,809. January 10, 1957.—H.P.M.V. FLUORESCENT ELECTRIC DISCHARGE LAMPS, The General Electric Company, Ltd., Magnet House, Kingsway, London, W.C.2. (*Inventor: Alfred Hamilton McKeag.*)

In high-pressure mercury vapour fluorescent lamps the fluorescent material is used either to improve the efficiency of the lamp by converting into useful visible light some of the non-visible ultra-violet radiation from the discharge which would otherwise be wasted, or to improve the colour-rendering properties of the light from the lamp by adding light of a colour (usually red or blue) in which the light from the discharge is deficient, or to attain both objects together. For some uses of the lamps it is desirable that the external dimensions should be as small as possible, for example for facilitating the design of optical apparatus with which the lamp is required to co-operate in a street-lighting fitting. Whilst the use of quartz glass (i.e. vitreous fused silica) for the discharge envelope facilitates the attainment of compactness, a difficulty arises in that a considerable amount of heat is generated by the discharge and the smaller is the outer jacket, the higher is the temperature it and the fluorescent material carried by it attain in operation. The efficiencies of most fluorescent materials decrease rapidly at elevated temperatures and the outer jacket must not be so small that the fluorescent material carried by it attains so high a temperature in operation as to be rendered uselessly inefficient. Recently, three new fluorescent materials have been discovered which have much better temperature stability than the sulphide materials used hitherto, are more efficient in that they are excited by both short wave and long wave ultra-violet radiation, and emit light which is rich in red wavelengths, so that they are very suitable for use in high pressure mercury vapour electric discharge lamps for attaining compactness with colour correction and good efficiency. These materials are barium strontium lithium silicate activated by cerium and manganese, magnesium arsenate activated by manganese, and magnesium fluorogermanate activated by manganese. It has now been found that where high compactness is the main requirement, consistent with good efficiency and a reasonable degree of colour correction, an even more suitable fluorescent material is calcium orthosilicate or a calcium strontium orthosilicate, activated by lead and manganese. Although the materials are not appreciably excited by long wave ultra-violet radiation, for which reason they would not normally be regarded as very suitable for use in high pressure mercury vapour lamps, they are found to be so very temperature stable that at very high temperatures their efficiency under short wave ultra-violet radiation exceeds that of the three recently discovered materials previously referred to under the combined long wave and short wave ultra-violet radiations in a high pressure mercury vapour electric discharge lamp. According to the invention, in a high pressure mercury vapour electric discharge lamp the discharge envelope is of quartz glass, the inner surface of the outer jacket is coated with a fluorescent material consisting only of calcium orthosilicate or a calcium strontium orthosilicate, activated by lead and manganese so as to be excitable to fluorescence by ultra-violet radiation of wavelength 2537A deg., and the outer jacket is so small that in normal operation of the lamp the temperature attained by all or the greater part of the fluorescent material exceeds 250 deg. Cent. A particular purpose for which the fluorescent material might be required with a very small outer jacket in a lamp of the kind specified is that of providing a light-diffusing screen round the discharge envelope for obtaining a small light source of relatively low brightness. By using calcium orthosilicate or calcium strontium orthosilicate fluorescent material to form the light-diffusing coating, the loss of lamp efficiency which would otherwise be obtained with the inactive coating materials, such as silica, is avoided, the calcium orthosilicate or calcium strontium orthosilicate material contributing fluorescent light to the lamp output even at temperatures as high as 600 deg. Cent. —*July* 13, 1960.

838,293. March 21, 1956.—OPERATING CIRCUITS FOR ELECTRIC DISCHARGE LAMPS, The Felden Engineering Company, Ltd., Feldenhurst, Felden Lane, Boxmoor, Hertfordshire. (*Inventor : Edward John Wyborn.*)

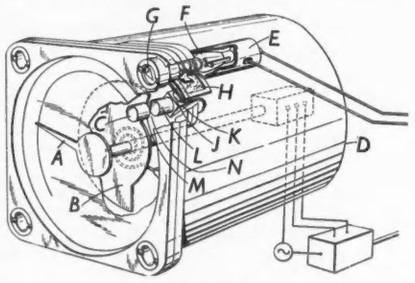
In order to reduce the weight and cost of control gear for fluorescent lamps, it has been proposed to use, in place of a choke, a resistance which can conveniently take the form of an incandescent electric lamp. This resistive ballast has the disadvantage of increasing the power lost, and the current through the resistance and therefore through the fluorescent lamp varies considerably when the mains voltage varies. The present invention, therefore, proposes the use of a resistive ballast for the operation of one or more fluorescent electric lamps comprising an iron wire filament mounted in a sealed bulb which is filled with hydrogen gas. The diameter, length and disposition of the filament and the gas pressure are adjusted so that the lamp current is maintained at a substantially constant and correct value over the voltage variation likely to be encountered in operation and one or more bi-metal switches, each of which comprises a pair of normally closed contacts, but which are opened by means of the bi-metal when the filament is heated by the passage of an electric current, are disposed in the bulb adjacent to the filament. The bi-metal switches may be used as starting switches for fluorescent lamps, for they are mounted in such a way that the heat generated in the filament causes the bi-metal to open the contacts after a short period which is sufficient to achieve the necessary pre-heating of the cathodes of the fluorescent lamp. Such a device is conveniently called a " starter/barretter." Two or more fluorescent lamps may be used in series with a single " starter/barretter " which contains two or more pairs of contacts operated by one or more bi-metal strips so that pre-heating of all the fluorescent lamp cathodes is secured, each lamp starting when the bi-metal strip or strips cause the respective contacts to open. This arrangement avoids the difficulty of synchronising separate series-connected starter-switches. The specification deals with the the application of the " starter/barretter" principle to operation of two or more fluorescent lamps in series and to use of the device in conjunction with a cathode pre-heating transformer.—*June* 22, 1960.

INSTRUMENTATION

841,028. July 24, 1957.—INDICATING INSTRUMENTS HAVING WARNING LIGHTS, S. Smith and Sons (England), Ltd., Cricklewood Works, Cricklewood, London, N.W.2, and Rolls-Royce, Ltd., Nightingale Road, Derby. (*Inventors : Philip Charles Pullen Thoma, Kenneth Arnold Basford and Anthony Gordon Neaverson.*)

This invention relates to indicating instruments in which a moving element is positioned in accordance with the value of the condition measured and in which means are provided for displaying an additional visible warning indication on the face of the instrument or other part when the value of the condition lies outside some predetermined range. The visible warning indication has, in the past, frequently been provided by means of an electric lamp controlled by a switch actuated by means responsive to the condition. It is an object of the present invention to provide an instrument of the kind referred to which does not require the provision of such additional condition-responsive means. The instrument shown in the drawing as an example is for indicating oil pressure and showing when it falls below some safe minimum level The instrument has a spindle on which is mounted a conventional indicating pointer *A* and a shutter *B* whose periphery is in the form of two arcs of circles of different radii centred on the spindle.

The dial is provided with an opening for a warning light. Disposed outside the cylindrical casing *D* is a smaller cylindrical casing *E* (a part of which is shown broken away) in which is mounted an electric light bulb *F*. A small coloured window *G* is used to indicate that the electric light bulb is functioning. The walls of the small and large cylindrical casings are provided with openings opposite to one another



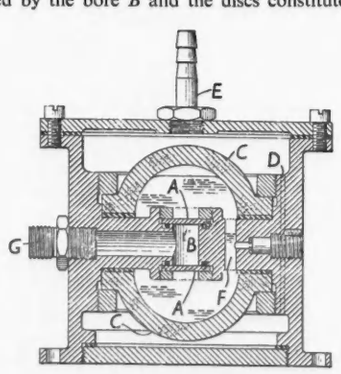
No. 841,028

and opposite the electric light bulb. A coloured screen *H* is secured over the opening in the large cylindrical casing, mounted within which, opposite the opening, is a radially extending " Perspex " rod *J*, the end of which remote from the opening abuts against the face of a right angle reflecting prism *K* formed from " Perspex." Another " Perspex " rod *L* abuts another face of the prism and extends forward at right angles to the first rod. Opposite and in line with the second light-transmitting rod is a third rod *M*. The second and third rods *L*, *M* are spaced apart providing a gap *N* into which the larger diameter portion of the aforesaid shutter may pass when safe oil pressure prevails. However, should the pressure fall below a predetermined limit the larger portion of the shutter passes out of the gap and the light rays reach the end of the third light-transmitting rod *M* which is located in the opening *C* in the face of the instrument. A modification is shown in the specification in which the shutter has a number of different coloured transparent sectors, portions of which may enter the gap and modify the light to indicate, for example, normal, caution and danger signals.—*July* 13, 1960.

VALVES

840,232. October 13, 1958.—NON-RETURN VALVES, United Kingdom Atomic Energy Authority, London. (*Inventors: Marshall Benjamin Bolt and Graham Llewellyn Hopkin.*)

This invention relates to valves for the passage of gas, and is capable of operating satisfactorily in any position. The valve body has an integral transverse wall bored and recessed to receive threaded rings which bear on porous discc of sintered stainless steel *A* and are sealed by " O "-rings. The chamber formed by the bore *B* and the discs constitutes the



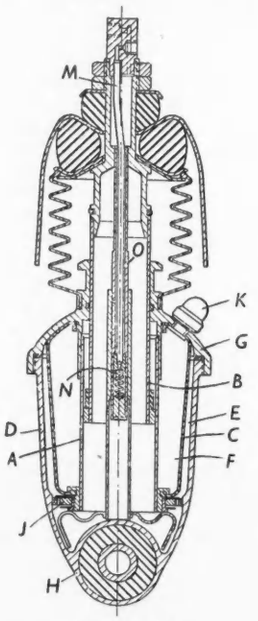
No. 840,232

inner chamber of the valve. Flanged, hollow, spherical, porous caps *C* of stainless steel, sealed on the transverse wall, provide the outer chamber of the valve, which contains mercury. Twelve holes *D* are bored in the wall of the body so that the spaces outside the spherical caps are in communication. Should the valve be employed in such a position that the lower cap *C* shown in drawing functions as the valve, gas will pass from the space about the cap through the holes *D* into the space about the other cap to the outlet *E*. The transverse wall is pierced by six holes *F* to allow free flow of mercury between the spherical caps. A stepped filler hole provided in the body wall for charging the valve with mercury, communicates with one hole *F*; and is closed by a screw threaded plug. The operation of the valve is as follows. When a gas is passed into the inlet *G* it passes to the inner chamber and through the porous discs into the mercury in the outer compartment. It bubbles through the mercury to the gas space above and from there passes through the porous caps and finally through the outlet. The valve, which may be used in any attitude, is positive in action and offers very low back pressure.—*July* 6, 1960.

SHOCK ABSORBERS

840,019. October 23, 1958.—HYDRO-PNEUMATIC SHOCK ABSORBERS, Daimler-Benz Aktiengesellschaft, Stuttgart-Untertürkheim, Germany.

The hydro-pneumatic shock absorber or spring leg, according to this invention, consists essentially of the working cylinder *A* with a shock-absorber piston *B* slidable therein. A diaphragm *C* divides the housing *D* into concentric chambers *E* and *F*. The cylinder is secured by its upper end to the cover *G* of the housing. The lower end of the cylinder is not connected to the housing, but projects freely into it to just above the eye *H* by which the shock absorber is articulated to an axle of a motor vehicle. A sealing bead at the lower edge of the diaphragm is clamped at the lower end of the cylinder. A member



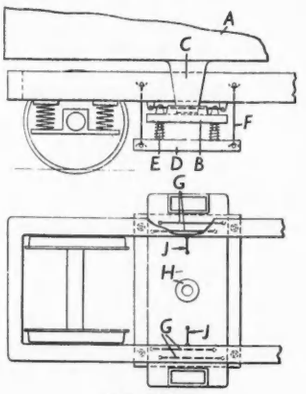
No. 840,019

on the cylinder securing the bead serves at the same time for the mounting of the valve *J*, which damps or throttles the flow of oil from the cylinder into the oil-filled chamber *E* or in the reverse direction. A valve *K* inserted in the cover serves for filling the chamber, bounded by the diaphragm *C* and cylinder *A*, with air at 50 atmospheres. The piston, projecting with its upper end from the cylinder, is mounted on or in the vehicle frame by means of elastic pads. The piston has an internal regulating piston, for adjustment of the height of the shock absorber and which is provided with an oil-inlet duct *M*, an oil-outlet duct and a non-return valve *N*. The piston *O*, which participates in the movements of the shock-absorber piston is slidable in a small control tube, which is held at the bottom of the housing by a resilient retaining member of sheet metal. The piston *O* and its tube are provided with appropriate ports and/or edges for controlling the admission or escape of oil. It will be seen that the position of the oil-filled chamber *E* ensures good cooling of the oil due to the air-flow sweeping past and that it is impossible for high-pressure air in the chamber *F* to diffuse through the wall of the housing or the cover. Finally, the separation of the air-filled and oil-filled chambers permits of a valve arrangement which gives a very short and simple shock-absorber construction. —*July* 6, 1960.

RAILWAY VEHICLES

840,356. August 29, 1958.—RAIL VEHICLES, The General Electric Company, Ltd., Magnet House, Kingsway, London, W.C.2. and North British Locomotive Company, Ltd., of 110 Flemington Street, Glasgow, N.1. (*Inventors: Brian Percival Bamfield, William Emlyn Lewis, John Dudgeon and Thomas Robertson Smillie McKinlay.*)

This invention relates to rail vehicles in which the superstructure is supported upon a bogie by a swing bolster with springs, the bolster being capable of transverse but not rotational movement relative to the bogie. Referring to the drawings, the superstructure *A* of the vehicle is supported on a traction beam *B* by side bearers *C* which incorporate sliding surfaces preferably in oil baths in known manner and which allow relative rotational sliding movement between the superstructure and the traction beam, give freedom in a transverse direction, and also allow tilting in the longitudinal plane. The traction beam is supported on a swing bolster *D* through secondary springs *E* and the bolster is suspended from the frame of the bogie by swing links *F*. Tractive effort is applied to the traction beam from the bogie frame by two pairs of traction links *G*, although only one pair could be used, and from the traction beam to the



No. 840,356

superstructure by a pivot pin *H* on the superstructure engaging a bearing in the beam. Besides applying tractive effort, the traction links prevent relative rotation between the bogie frame and the traction beam. The complete assembly of the traction beam, bolster and swing links is therefore constrained to rotate with the bogie and relative to the superstructure against the friction of the sliding surfaces of the side bearers *C* on the ends of the traction beam. The only relative movement at the pivot pin to the beam is rotational and longitudinal tilting, this eliminating any requirement for transverse sliding motion which is common in previous bogie constructions. Transverse movement between the superstructure and bogie frame is permitted by the action of the swing links and this movement is restrained by a spring device which may be designed to have a linear or non-linear spring characteristic as required and which in either case may be used with suitable damping. The device may be in the form of a bell crank lever and spring arrangement *J* between the bogie frame and traction beam or a buffer arrangement could be used. It will be appreciated that this bogie construction is suitable for cases where, because of weight transfer considerations, a low thrust point below axle level is required. Further, many of the rubber types of springs, linkages and pivots now available or combinations of rubber and steel springs or pivots may be used.—*July* 6, 1960.

Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office not later than a fortnight before the meeting. In all cases the TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

BRITISH INTERPLANETARY SOCIETY

Mon. to Sat., Aug. 15 *to* 20.—Royal Institute of Technology, Stockholm, Sweden, Eleventh International Astronautical Congress.

INSTITUTE OF METALS

Tues., Aug. 16.—17, Belgrave Square, London, S.W.1, " The Physical Nature of Plastic Flow," J. J. Gilman, 6.30 p.m.

ROYAL INSTITUTION OF CHARTERED SURVEYORS

Tues., Aug. 30 *to Sat., Sept.* 3.—The University College of North Wales, Bangor, Annual Conference, 1960.

Advanced Engineering Courses

Production Engineering. IMPERIAL COLLEGE OF SCIENCE AND TECHNOLOGY, South Kensington, London, S.W.7. A full-time course in production engineering commencing in October. The course will be of one year's duration and successful candidates will be awarded the D.I.C. Students will be required to take three compulsory subjects : Industrial engineering ; management and industrial administration, and statistics and statistical methods. Prospective entrants should possess a degree or equivalent, together with some practical experience.

Production Planning and Control. UNIVERSITY OF BIRMINGHAM, Institute for Engineering Production, " Southfield," 16, Norfolk Road, Edgbaston, Birmingham, 15. Residential executive course, September 19 to 30. The primary aim of the course is to discuss methods of production planning and control and the application of systematic analysis to these functions with a view to the improvement or organisational and production efficiency. The course is intended for industrial executives, senior production engineers and controllers, O. and M. personnel and other specialists in related fields. Fee sixty guineas.

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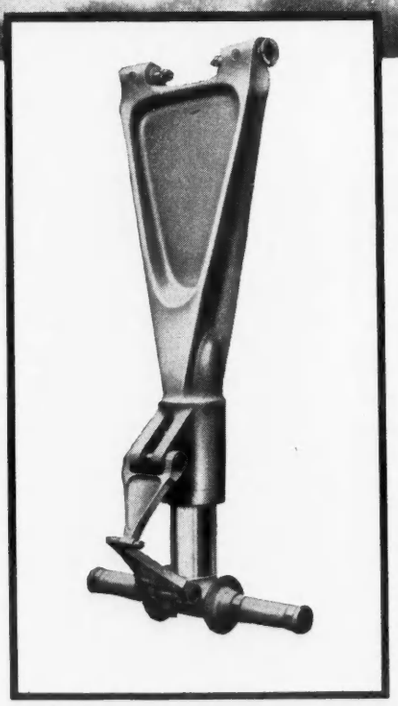

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2" dia.	Oil quenched 830°C.	60	70	20	53
6" sq.	Oil quenched 830°C. tempered 590°C.	62	71	18	39

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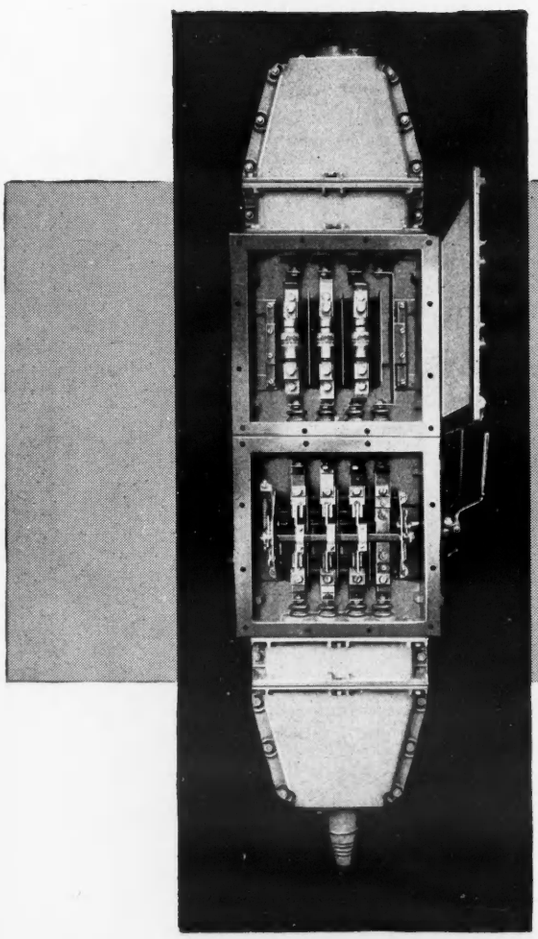

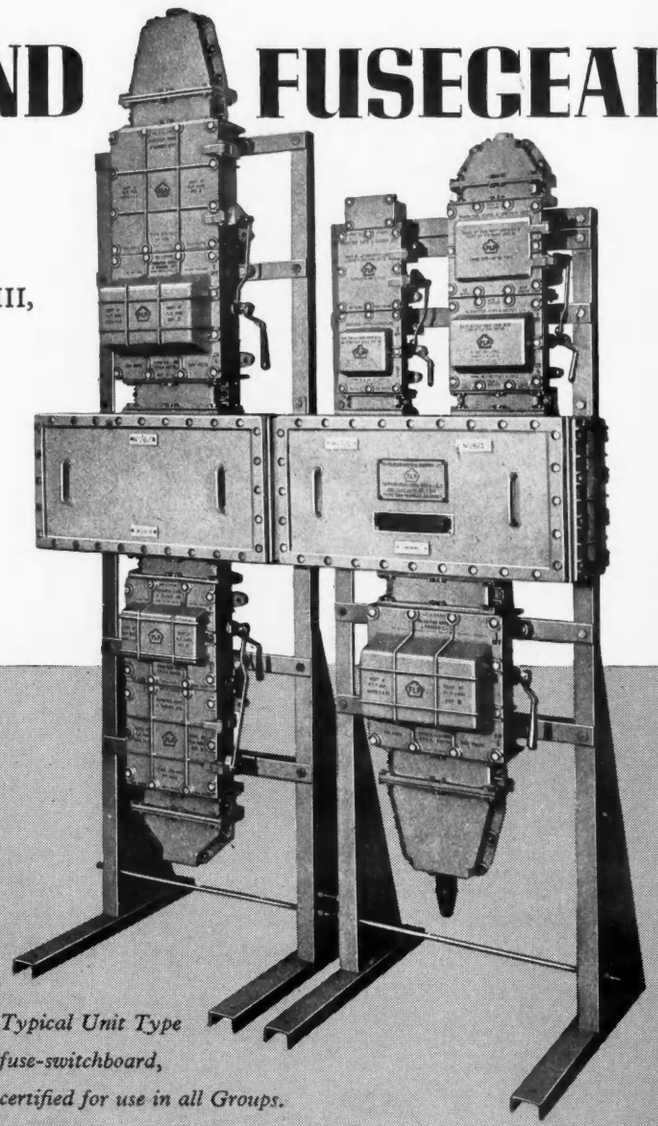

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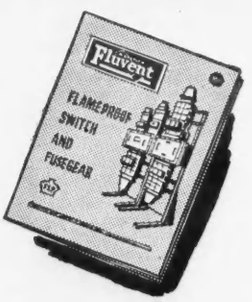

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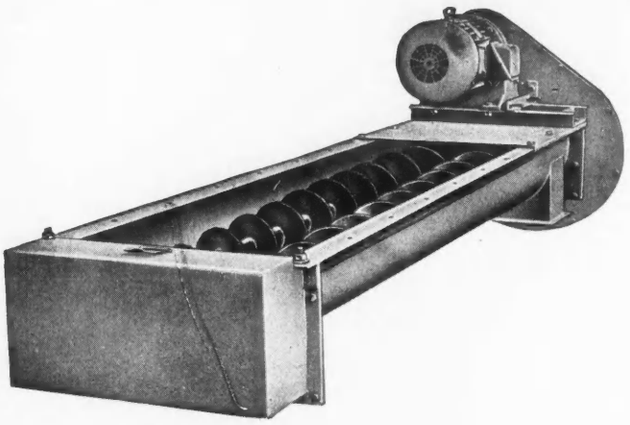

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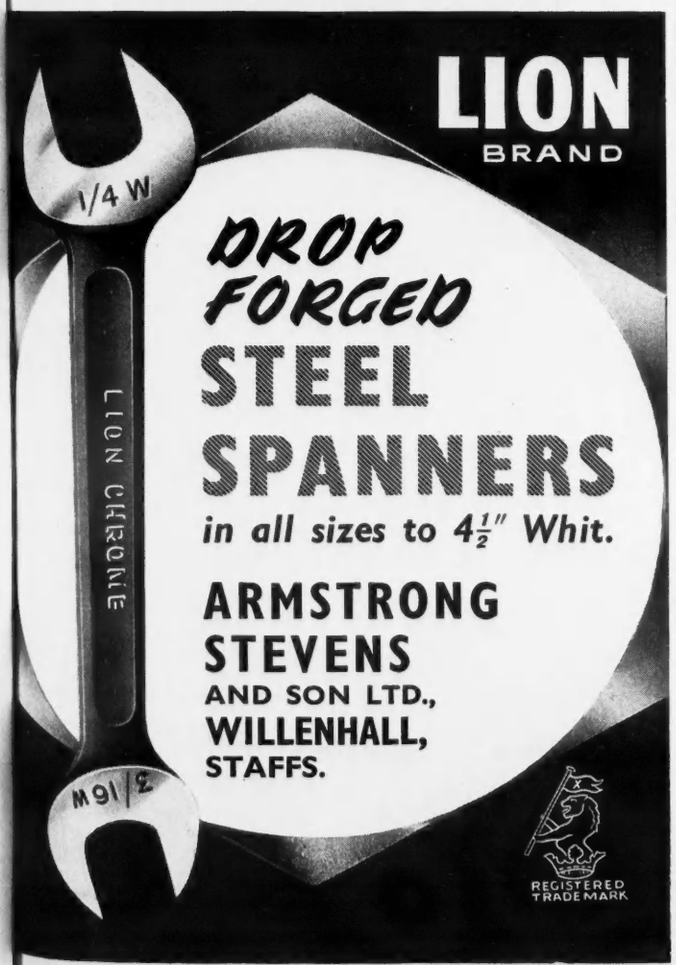

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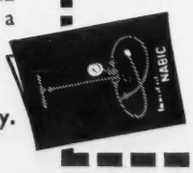

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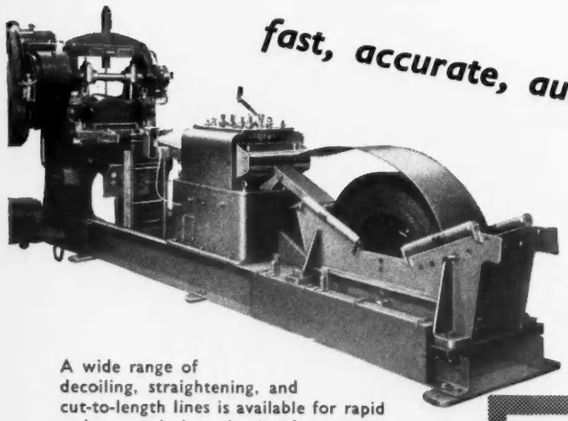

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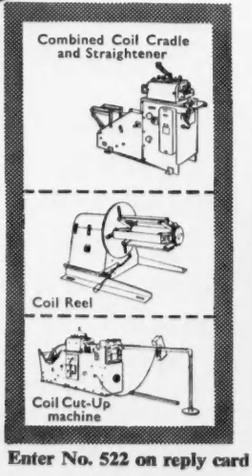

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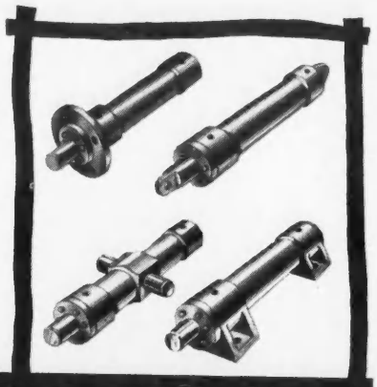

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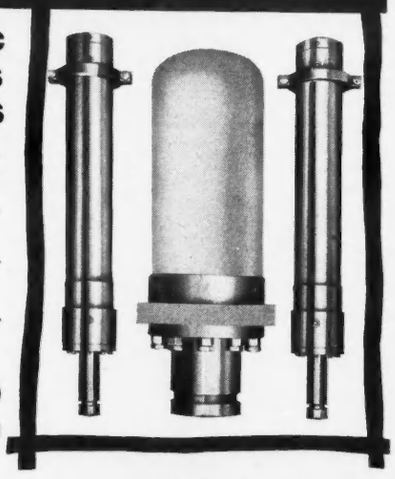

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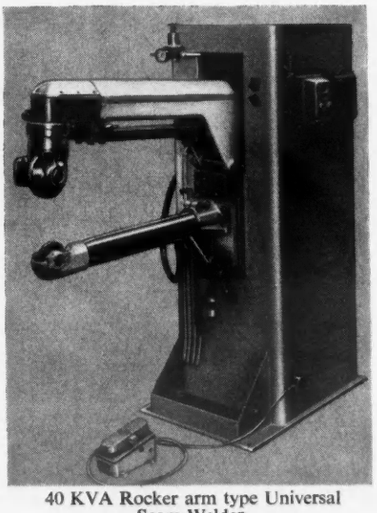

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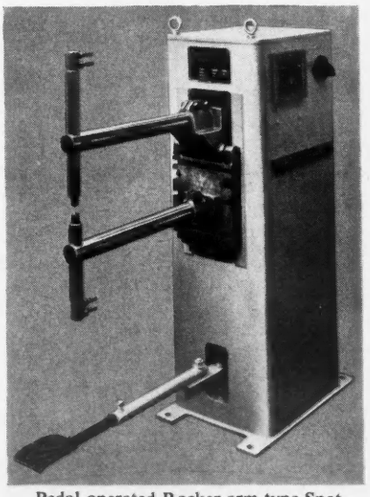

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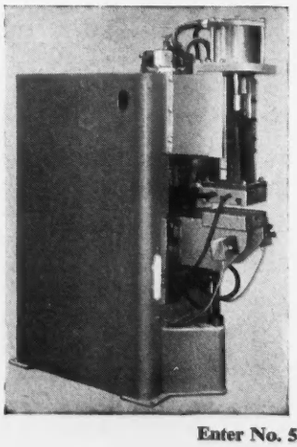

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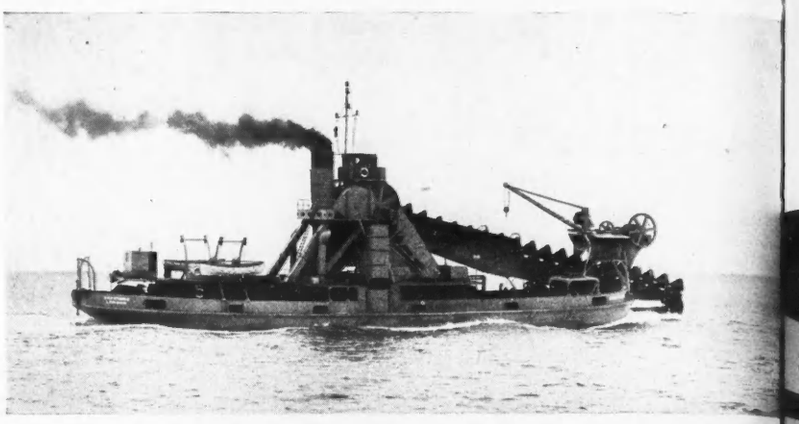

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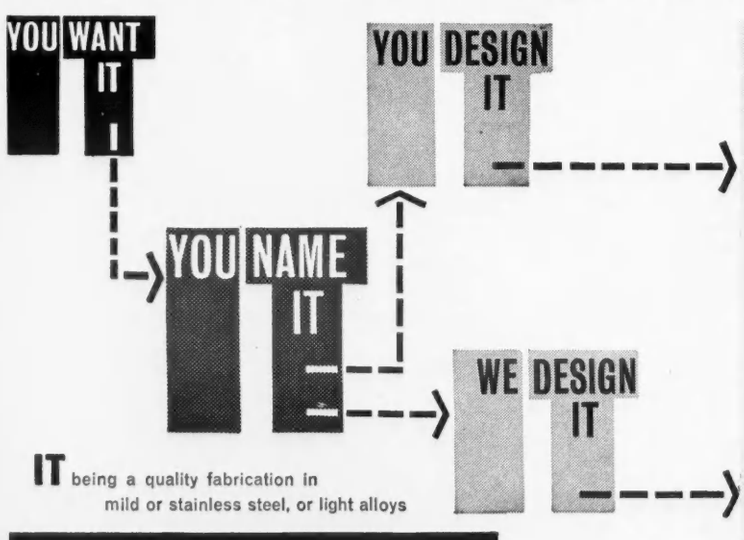
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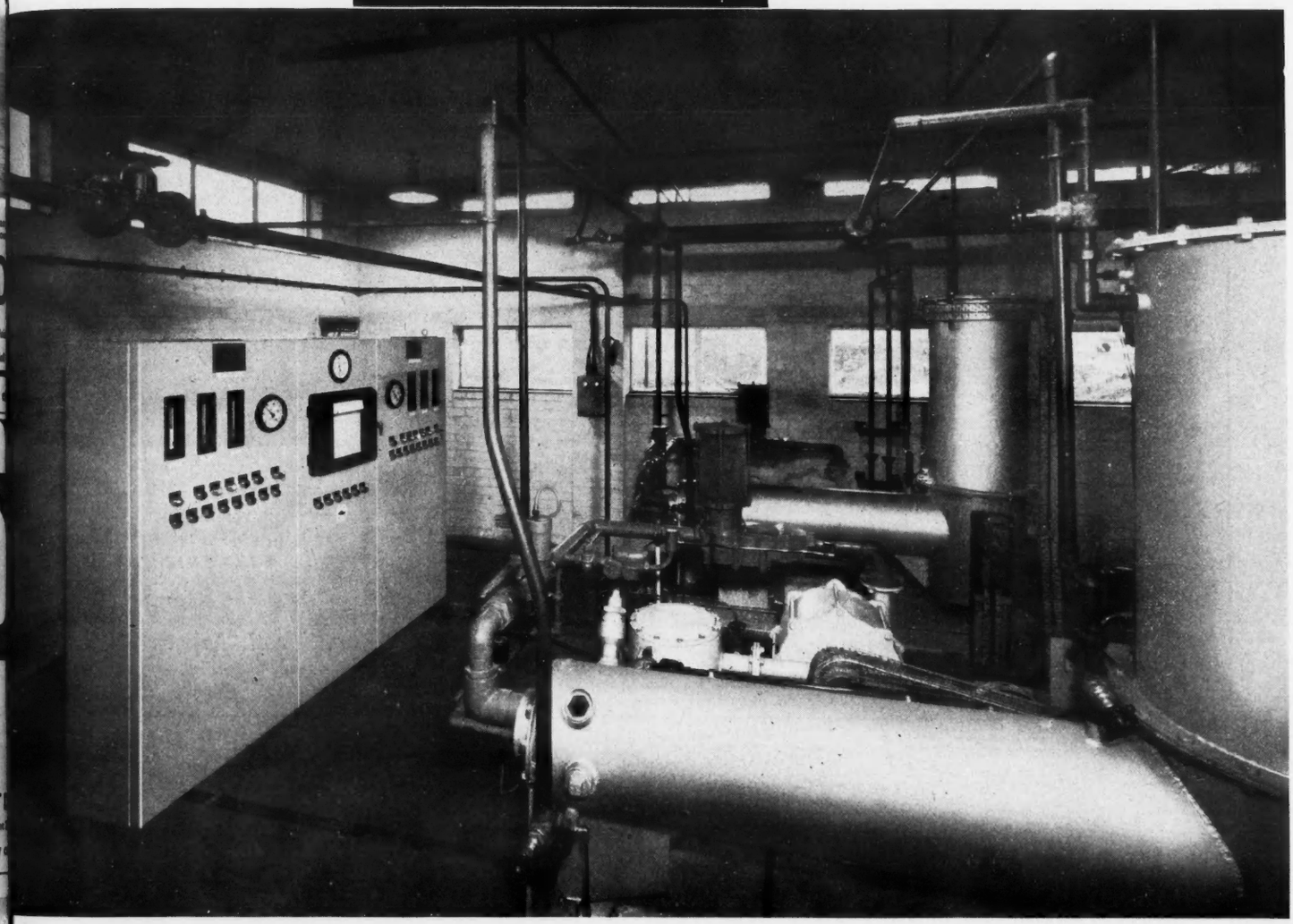

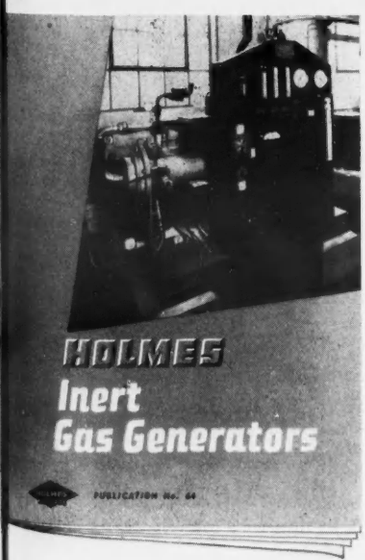

The photograph shows the twin 2,000 c.f.h. inert gas generators installed at the Maydown Works of Messrs. Carbide Industries Ltd. The installation also includes; a central control panel, soda washers, high pressure compressors, Holmes-Kemp Dryers and a storage receiver. The inert gas, which is used for blanketing operations, is continuously monitored by a gas analyser controller to ensure that it is of a consistent high quality.

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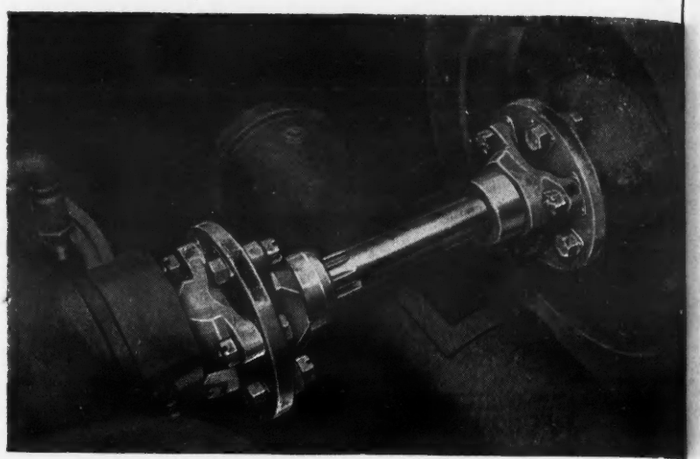

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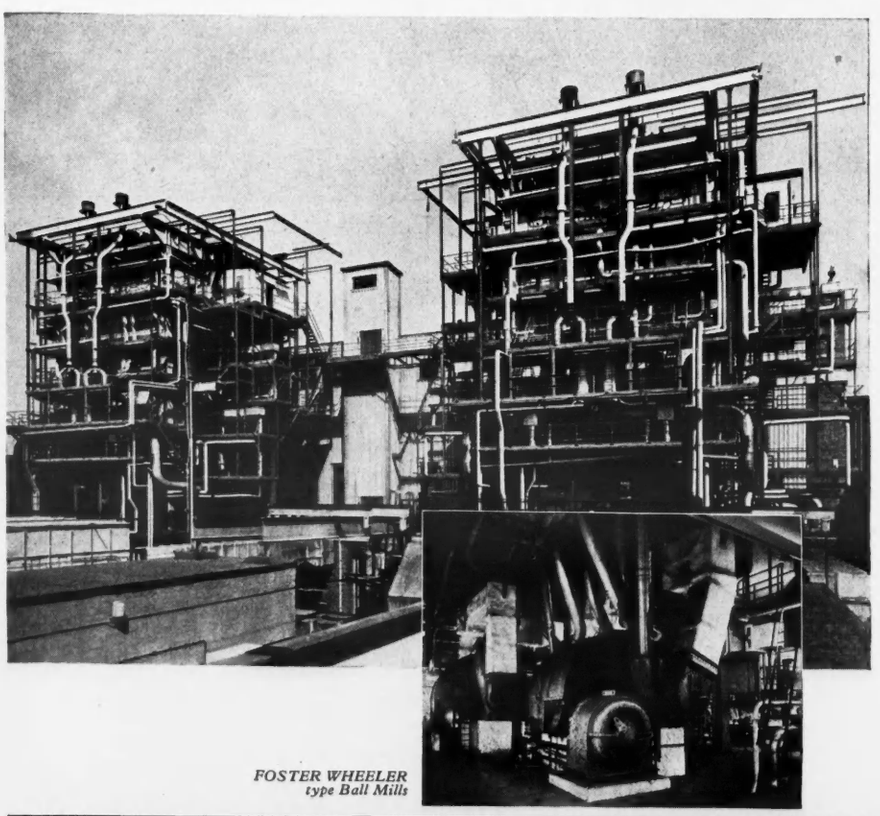

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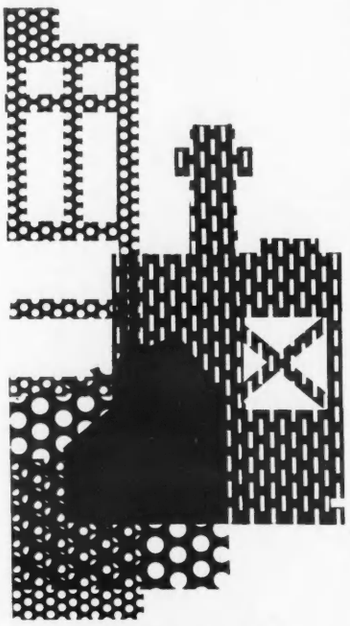

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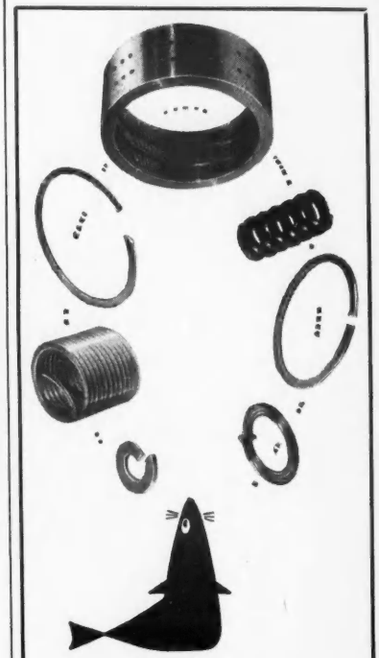

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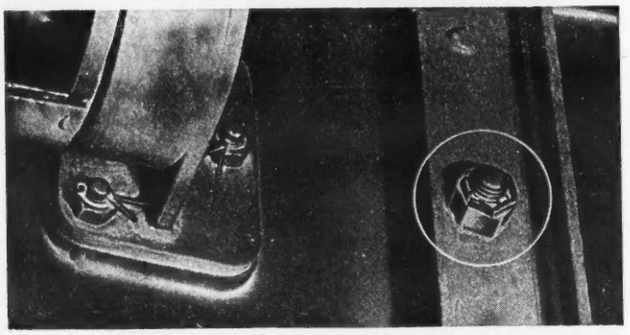

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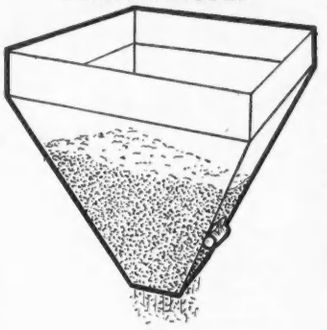
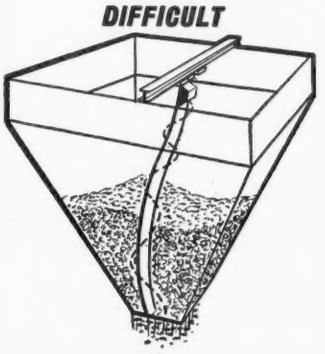


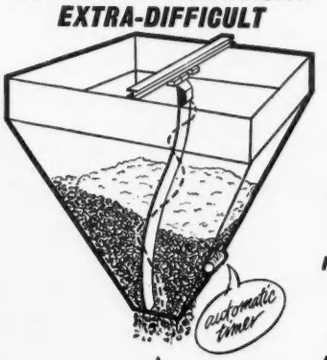
The installation of an external vibrator to a steel hopper.

DIFFICULT



The vibrating reed for application where external vibration is impractical due to structural or other difficulties and if the bunker is made of concrete.

EXTRA-DIFFICULT



A combination of internal and external bunker vibration. Where the external vibrator is timed for 'on and off', the vibration frequency, on slowing down, goes through the natural resonance of the bunker, irrespective of load material contained.

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The primitive, inefficient method commonly used for clearing material which sticks in a storage bunker is by applying a sledge hammer to the side of the hopper. This is a form of low frequency, uncontrolled vibration. When vibration is applied at the *correct* frequency, the *correct* amplitude and the *correct* point of application, almost any material can be satisfactorily discharged.

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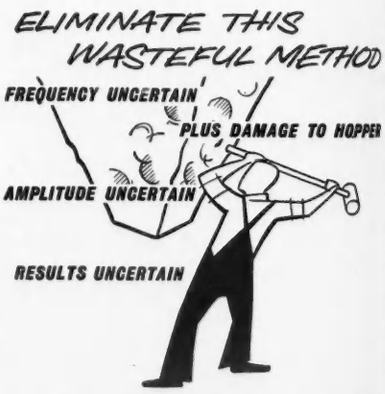
It would pay you, therefore, to make use of our experience and to consult us on your particular problem. Send for relevant details and information sheet.



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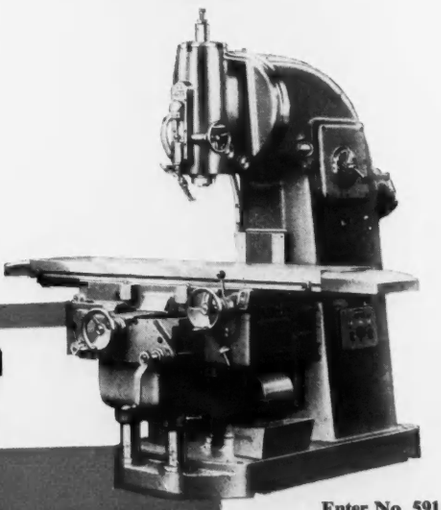

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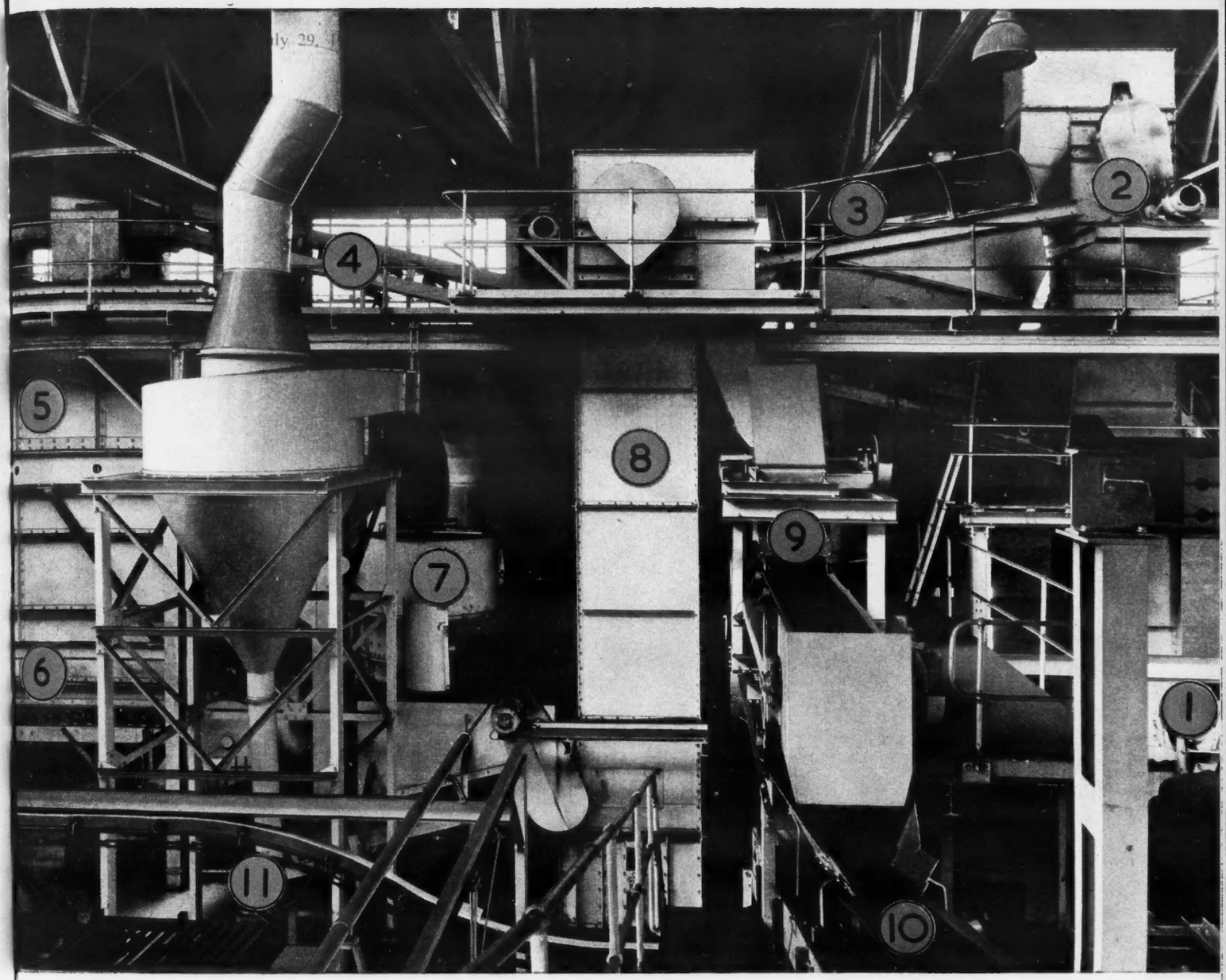

The illustration shows that part of a **MORRIS** foundry sand and mechanization plant which reconditions knocked-out sand. At **1**, sand coming from the knock-out via an apron plate and belt conveyor passes beneath a magnetic separator (to remove tramp iron) and falls into the boot of a belt-bucket elevator **2**, discharging into screen **3** onto belt conveyor **4**, which in turn discharges into sixty-ton storage hopper **5**. The flat belt conveyor **6**, under the hopper, pours sand into the skip which feeds the mulling machine (known as the Speedmullor). This machine **7**, providing a rapid mulling cycle with close batch control, discharges the sand into belt-bucket elevator **8**. From thence, the sand proceeds via belt conveyors **9** and **10** to the moulders. The overhead chain conveyor **11** serves the core shop with sand and also takes the cores to the stoves and to the moulders.

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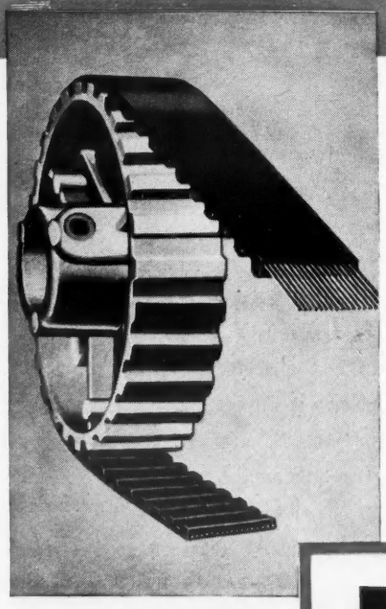

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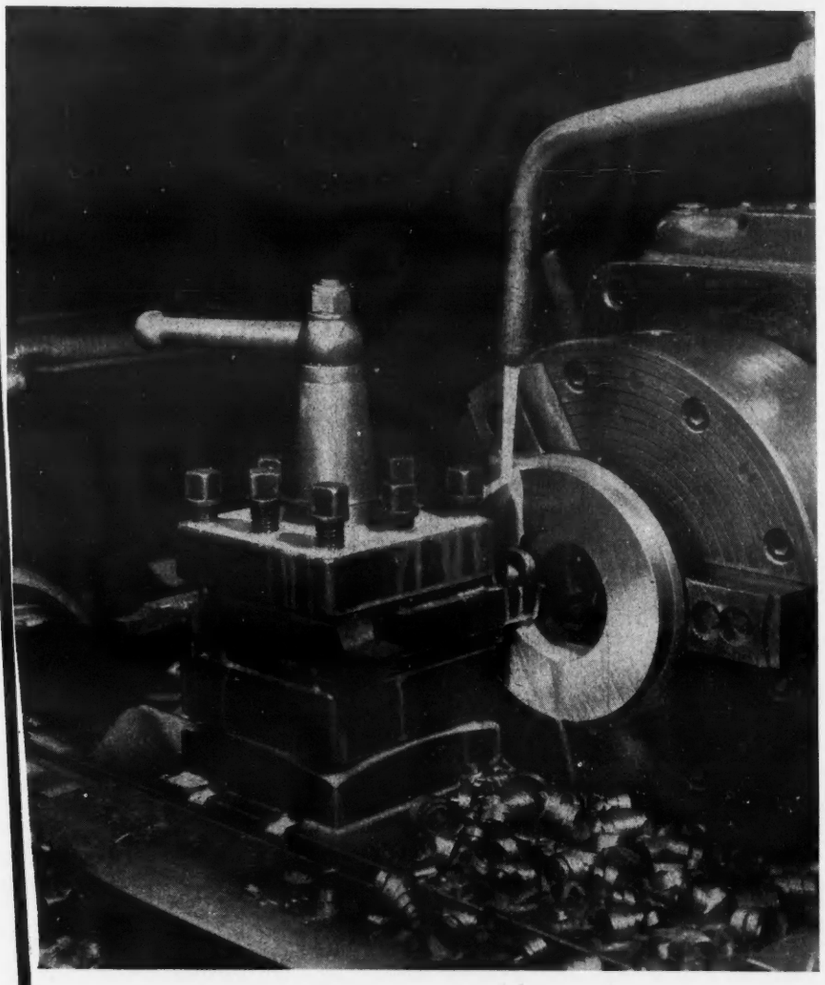

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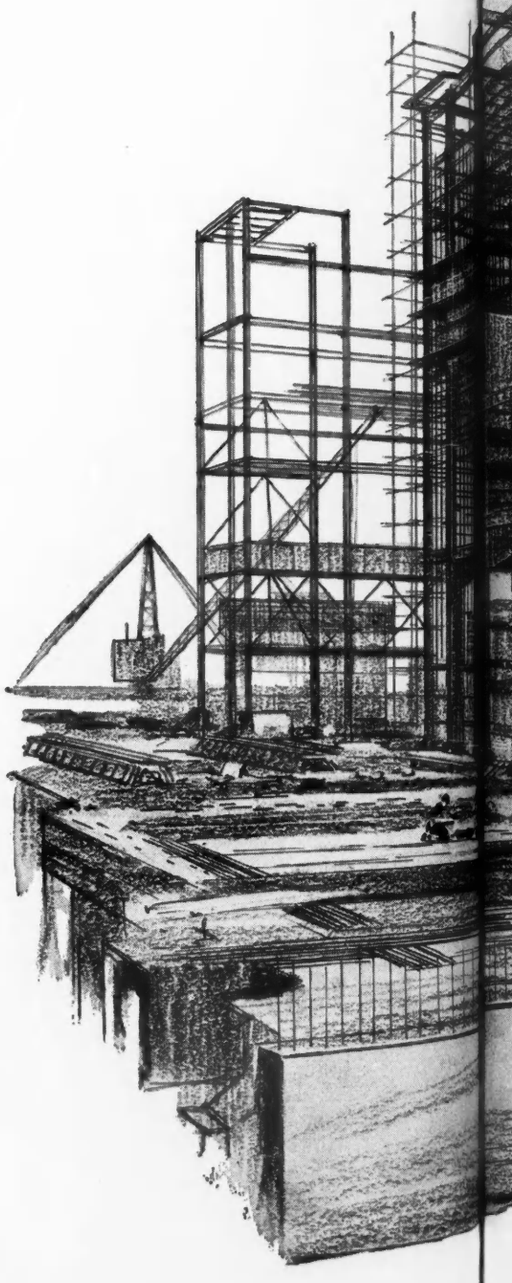

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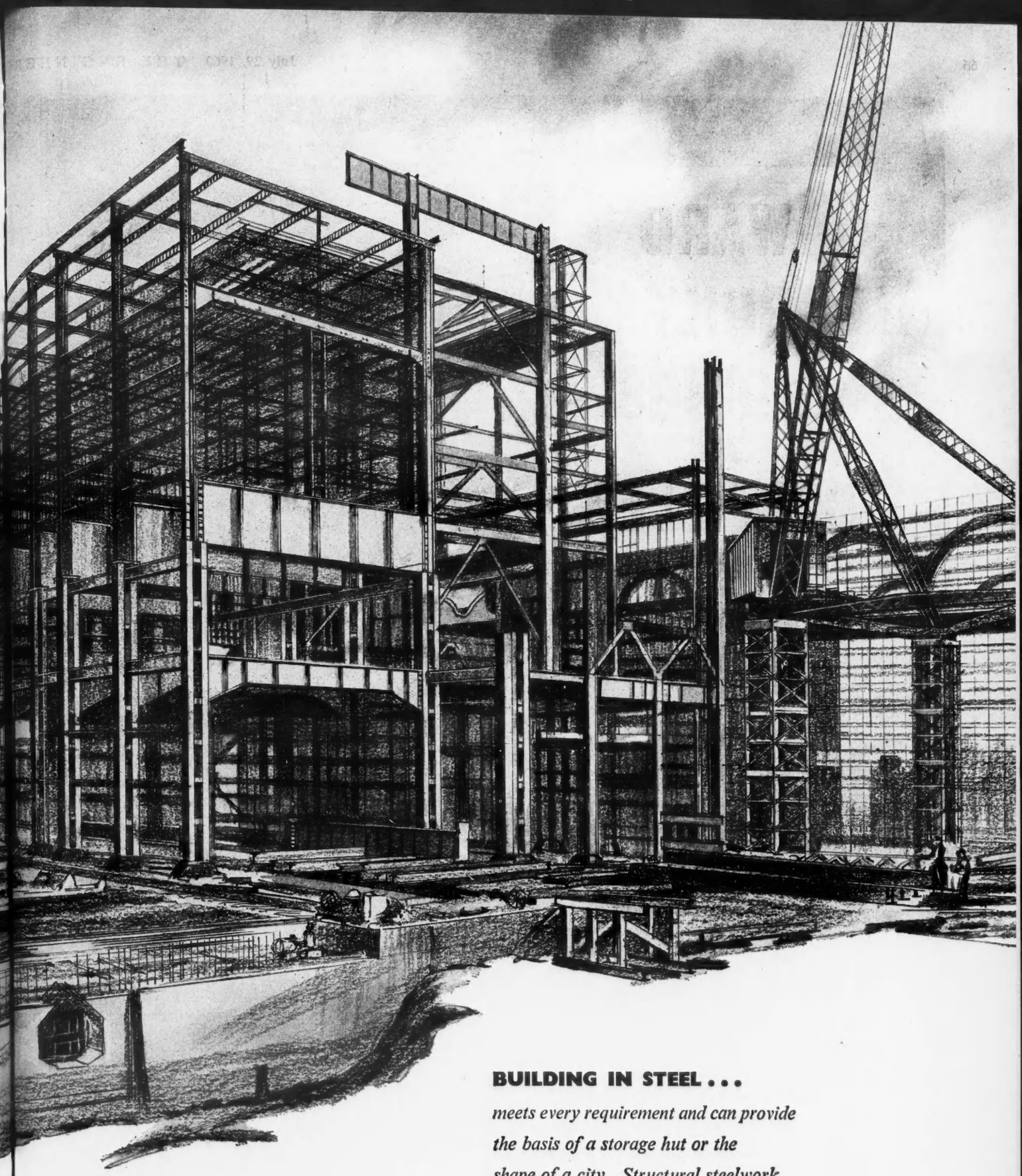

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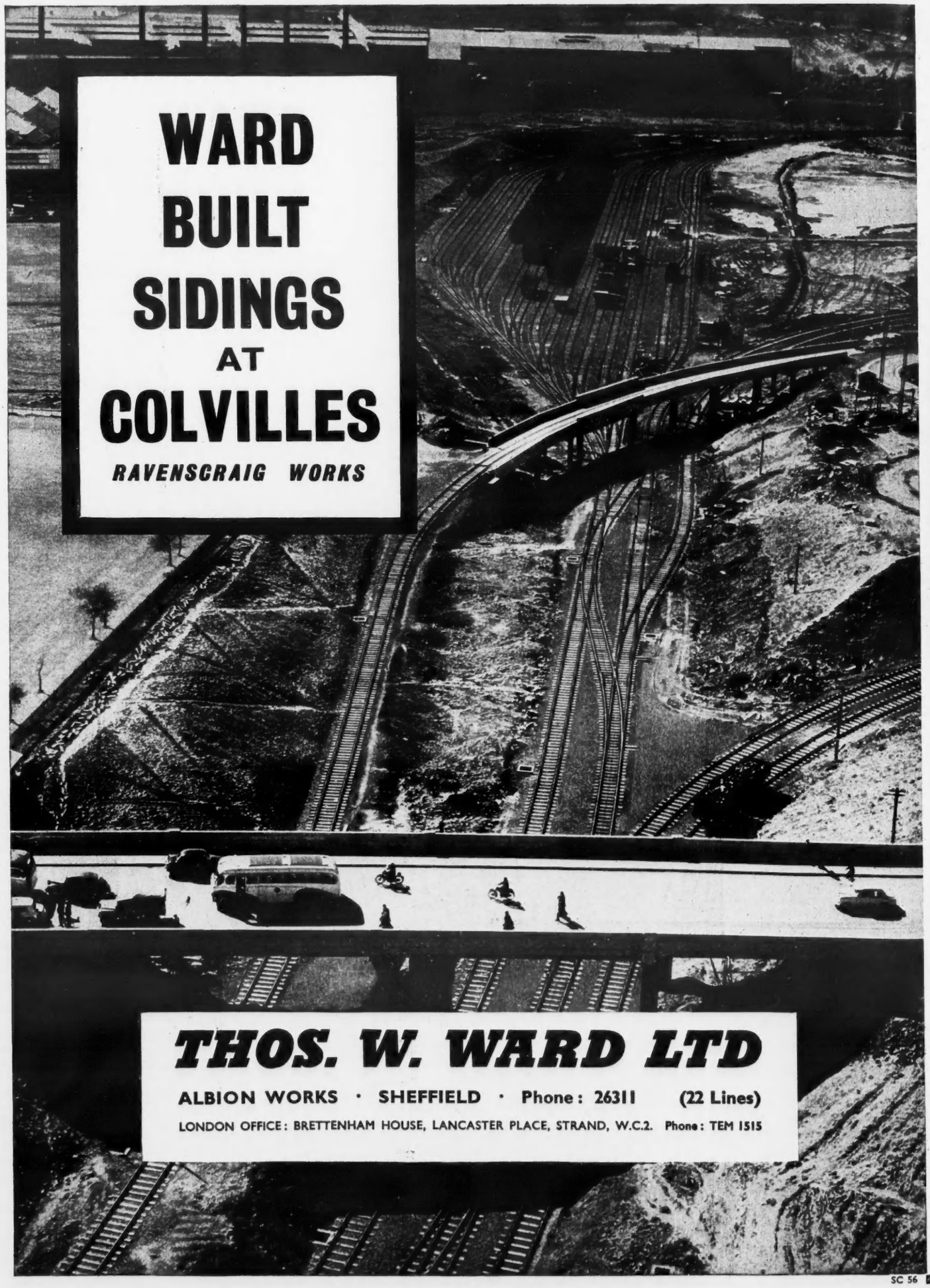

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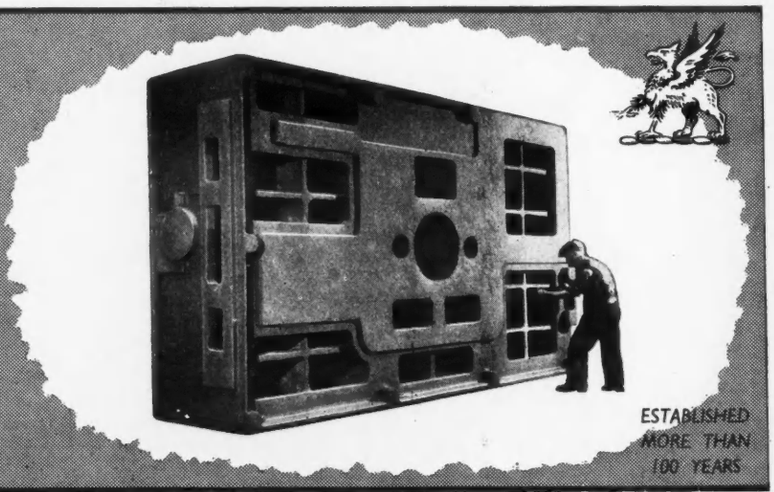

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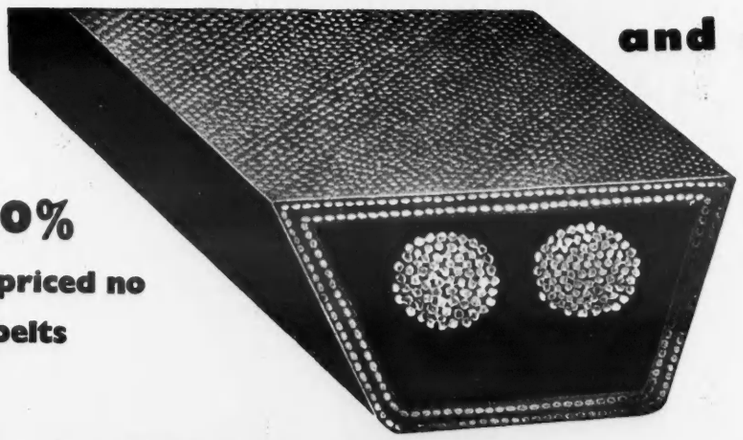

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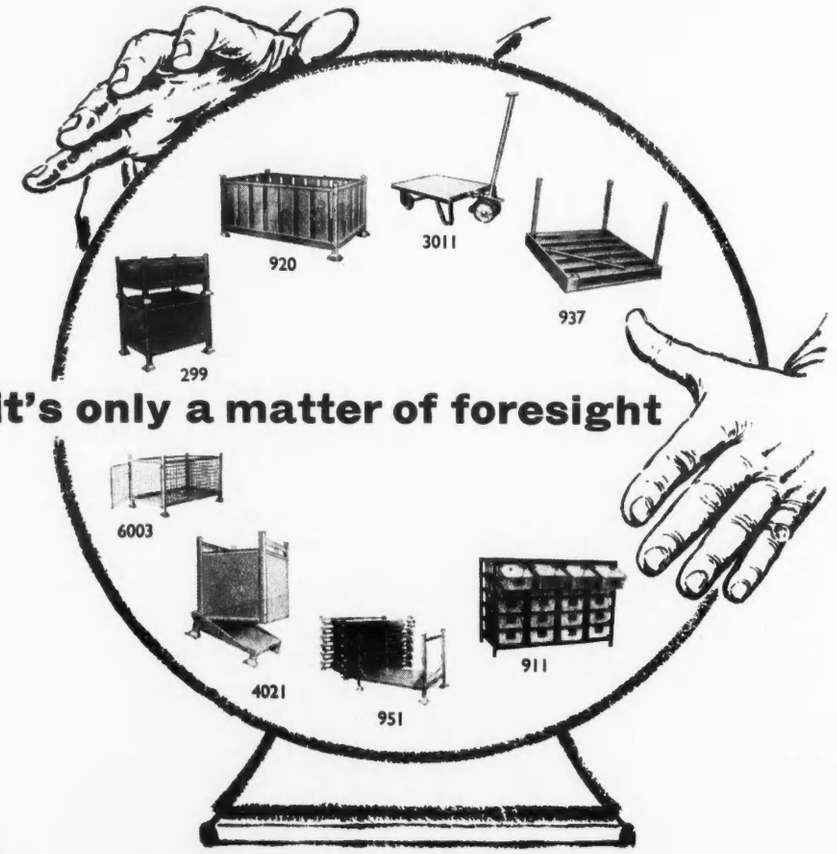

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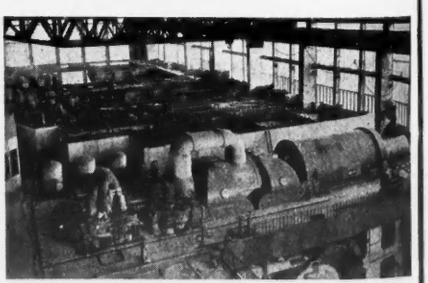

Photograph by courtesy of A.E.I. Turbine-Generator Division

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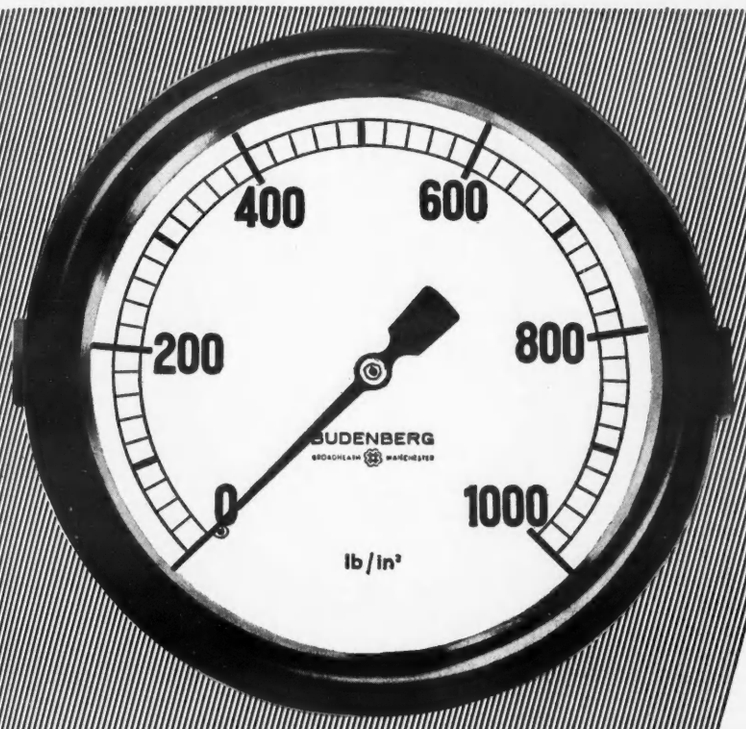

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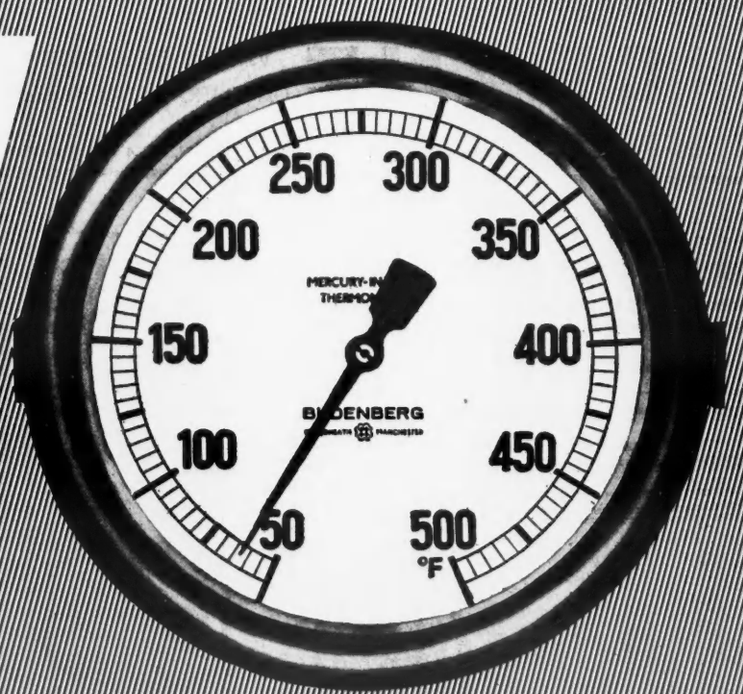

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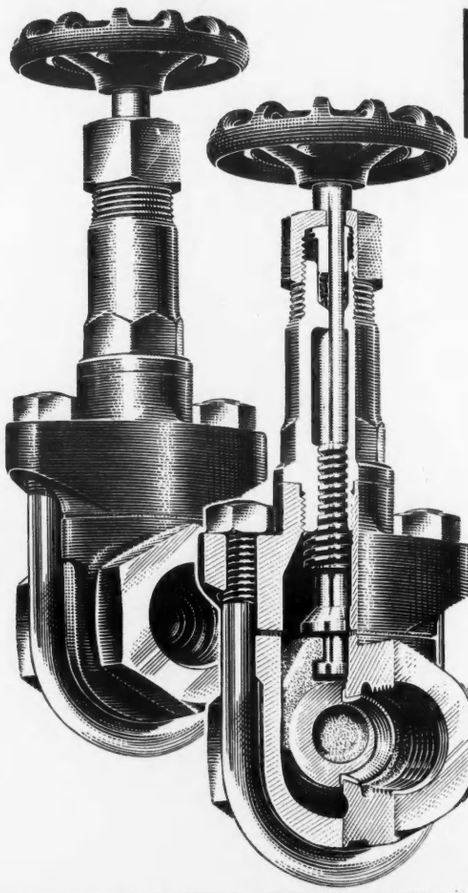

C

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. . . with rising stem, inside screw and wedge disc.

This range of valves is particularly recommended for pipelines that carry considerable quantities of dirt and other foreign matter. Their clamp construction enables them to be quickly and easily dismantled for cleaning or repairs. They are compact and light in weight. The disc is attached to the stem by means of a tee-slot, a feature that provides a safe but flexible coupling. Bronze trimmed valves are recommended for steam, water, air and non-corrosive oil lines. All-iron valves are recommended for oil, gas and other fluids that corrode bronze but not iron or steel. Screwed and Flanged valves are supplied to British and American Standards.
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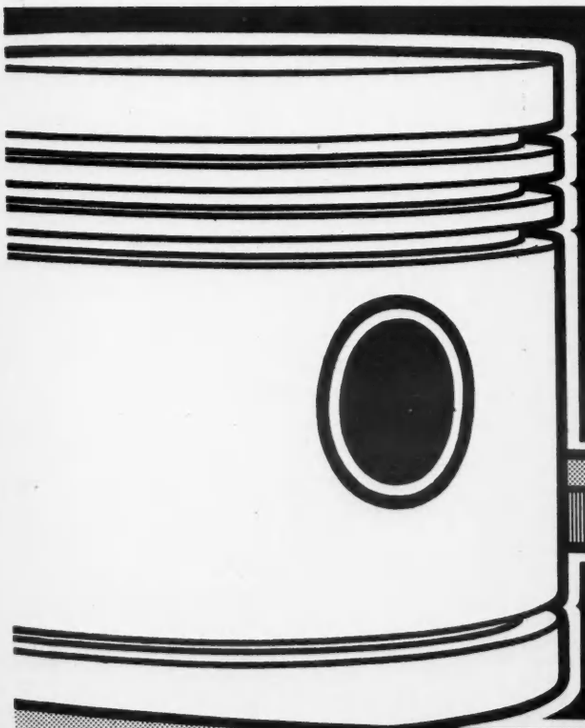

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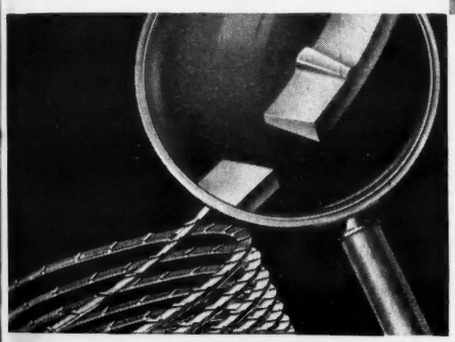
They are permanent, cleanable filters, efficient and reliable in action.

Six SIZES FROM 2 g.p.m. TO 35 g.p.m.



Purolator metal edge filters consist of a patented edge-wound metal ribbon of tapering cross-section that presents a rigid surface to the incoming fluid. The precision formed ribbon is closely wound under tension on to a supporting frame and securely fixed at each end. Projections on the ribbon, which are of uniform height and formed at defined intervals along its surface, give a degree of filtration from ·002" to ·020" as required. These filters can be supplied in brass, monel metal or stainless steel materials.

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ONE OF THE AUTOMOTIVE PRODUCTS GROUP

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OSOTITE—the modern scientific sealing which has been proved by rigorous tests to be the perfect jointing for smooth surface and screw unions. OSOTITE is a simply applied liquid compound, impervious to heat, petrol, oil, grease, water and steam which ensure in a few minutes a HIGH PRESSURE GAS, AIR or WATER-TIGHT JOINT. Write for full details and prices.

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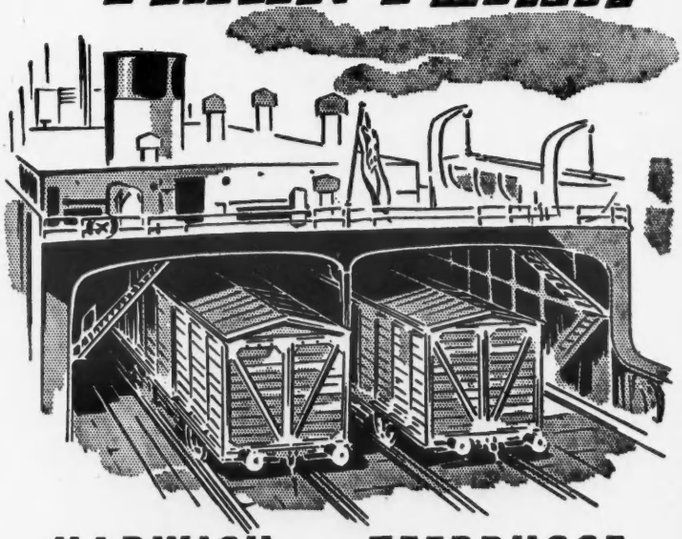

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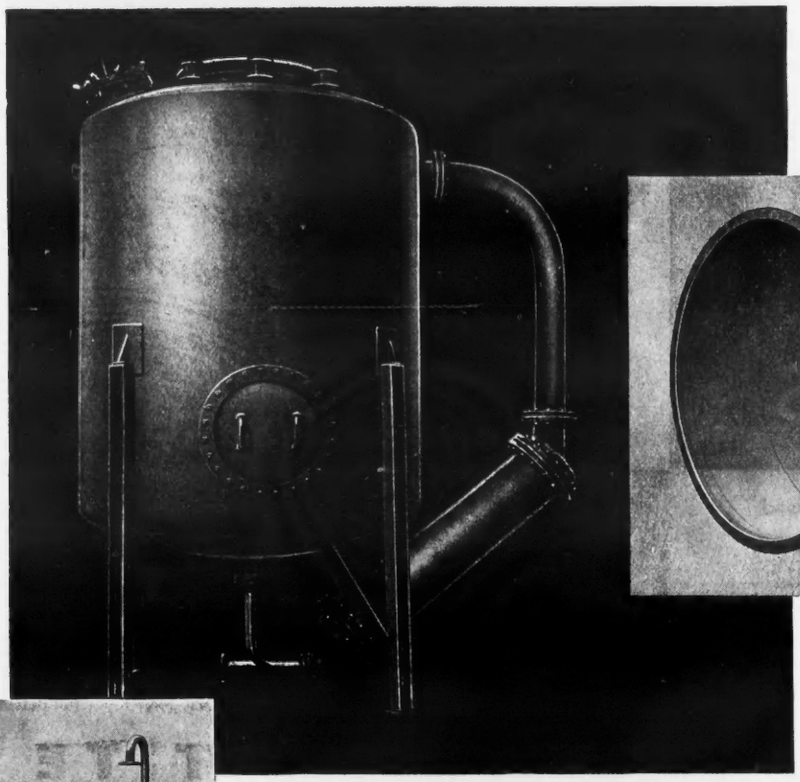
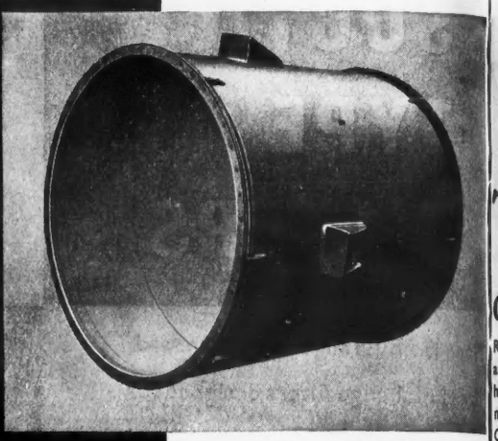
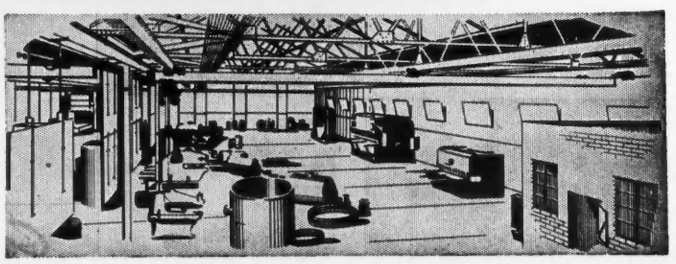


1,000 gall. kettle in ¼" copper. Lynx Quasi-arc welded.



Stainless steel vessel with mild steel jacket

12,000 gallon water separator



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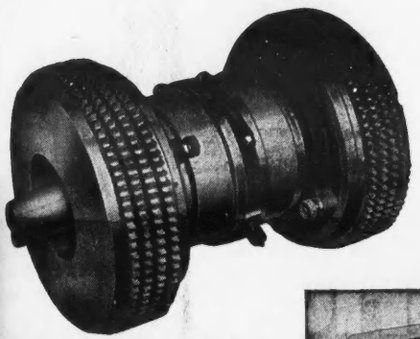

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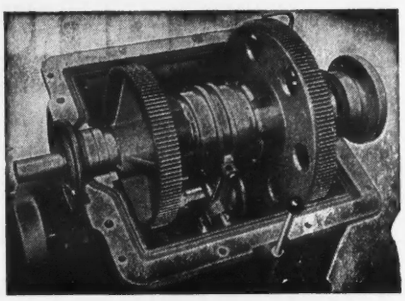

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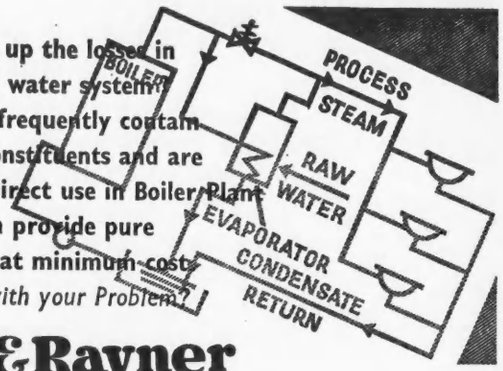

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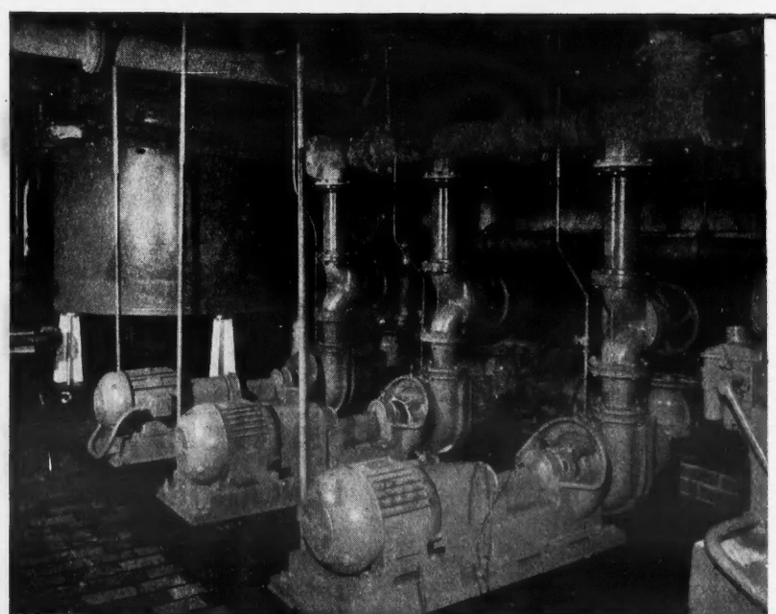

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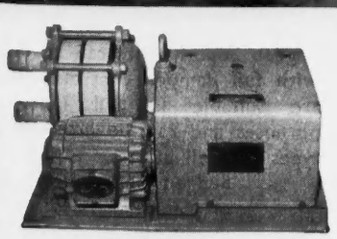
Sulphuric Acid and contaminated wash waters on pickling tanks and continuous pickling plants

Chromic Acid and Nickel Solutions for electrolytic plating plants including pumping to filters, etc

Waste pickle liquor and acidic effluents for neutralisation prior to disposal

Pumping of demineralised water

(Top left) Large battery centrifugal acid pumps
(Bottom left) Close-up view of diaphragm pump similar to the hand operated unit but arranged for motor drive
(Bottom centre) Hand operated portable diaphragm pump for emptying carboys or tanks and for general duties.
(Bottom right) Portable rotary displacement pump pumping plating solutions in the motor car trade



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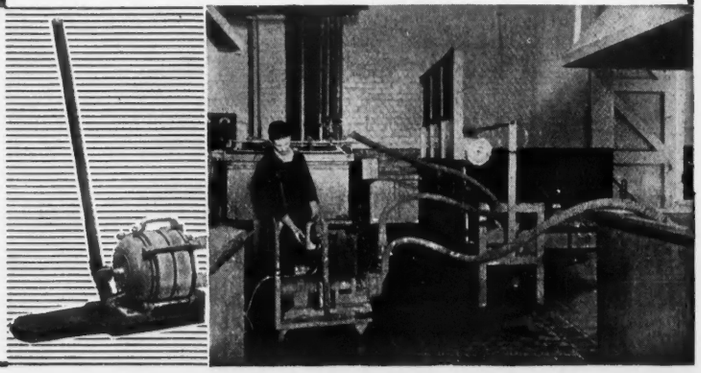

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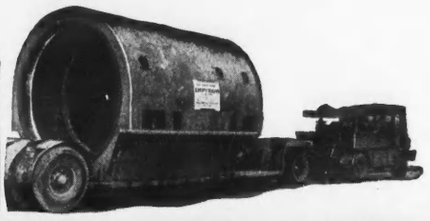
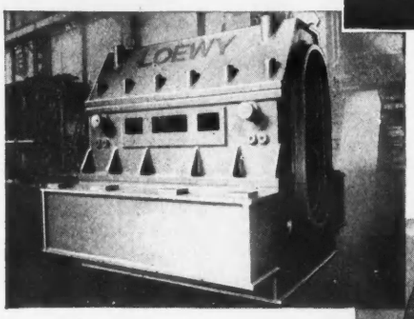
Heavy Welded Fabrications





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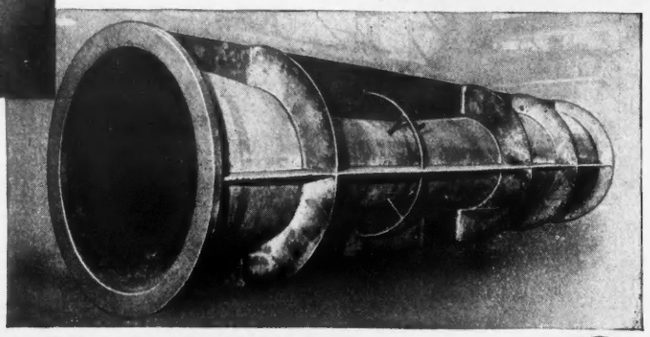

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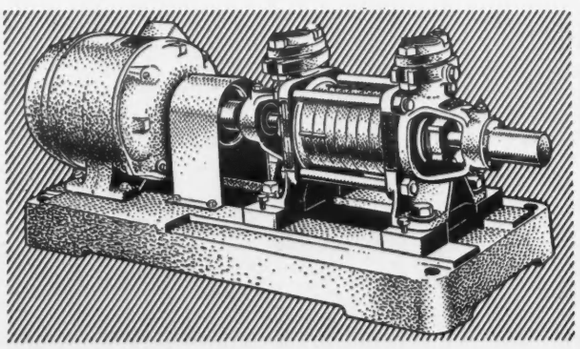

BERESFORD *multistage pumps*

BM 271

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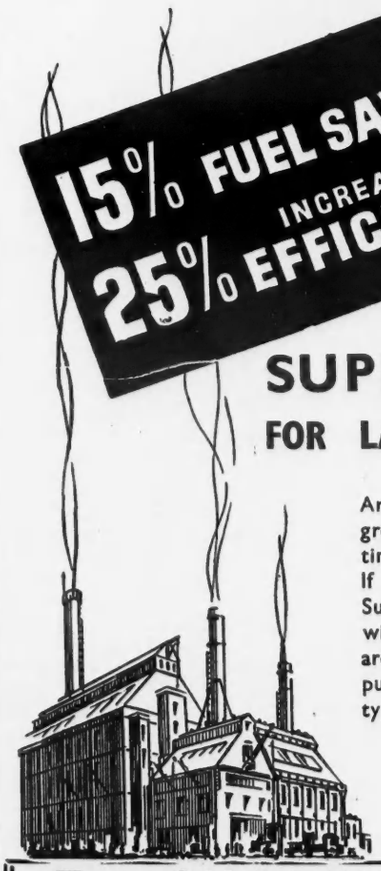

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WITHSTANDING
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PLUS POINTS

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- *High tensile wire-braid reinforcement with special spiral asbestos cord which incorporates a static conducting wire.*
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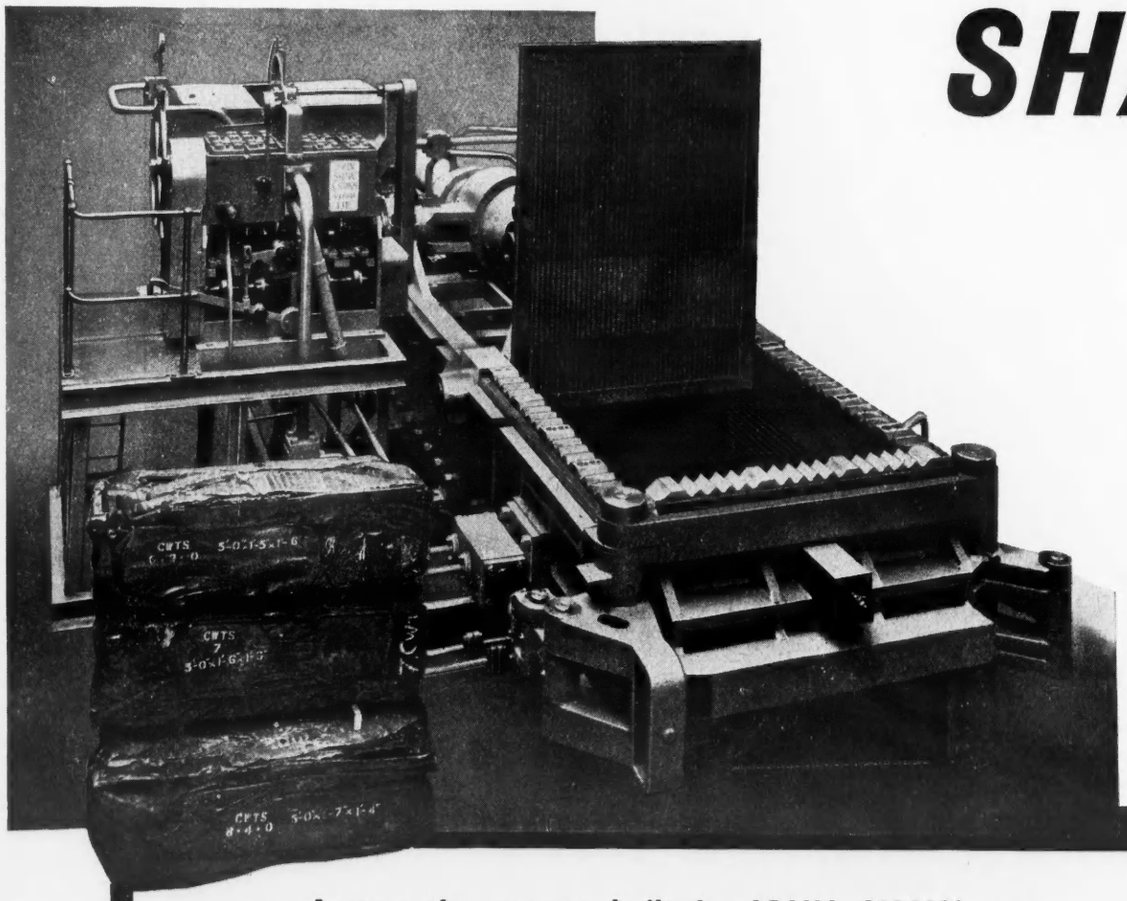

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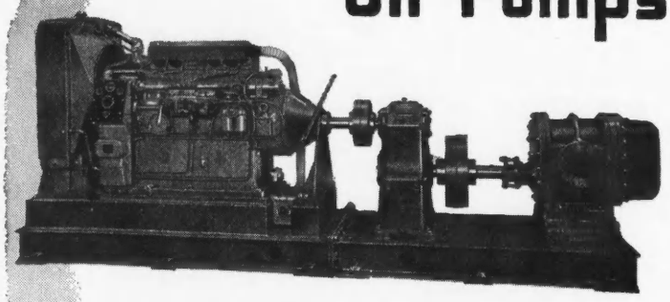

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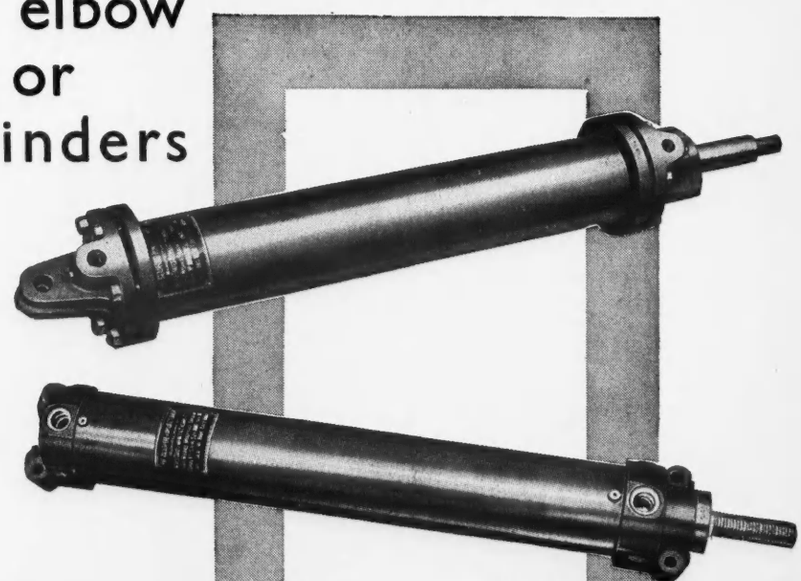

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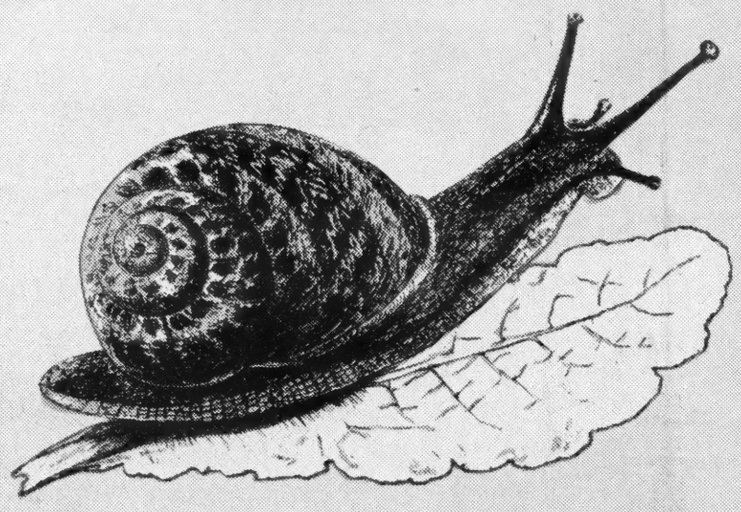

MADE TO MEASURE

The snail, most thoughtfully, goes to some pains to reconcile his own needs with those of the conchologist.

● As home and protection, his shell must be tough, portable, and very much made to measure. At the same time, it must have just those qualities which—in due course—will delight the collector.

● Sheet steel from the City of Steel follows no less closely its intended purpose. Each order is treated as a separate assignment so that you, the manufacturer, get the particular kind of steel your product needs.

● Steel, in fact, made to measure—to your exact requirements.

THE STEEL COMPANY OF WALES LIMITED

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KNOW YOUR BEARINGS

Apprentices
Draughtsmen
Designers
Production Engineers
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No I The Ball Journal

Naturally the series begins with the single row ball journal bearing, the engineer's "maid-of-all-work", it being by far the most used of all bearing types.

It is intended primarily for dealing with journal loads but is also quite suitable for taking thrust loads in either direction with or without journal load. The balls run in deep raceways or tracks designed to afford maximum support consistent with freedom in running.

The latest manufacturing techniques enable us to produce an even better bearing by improving track geometry and track finish, as well as the accuracy of the assembled unit. The ball journal is also supplied slightly smaller on the outside diameter for location duty.

HOFFMANN BALL JOURNALS
are made in the following sizes:—
IN INCH SIZES—EXTRA LIGHT, LIGHT AND MEDIUM
IN METRIC SIZES—LIGHT, MEDIUM AND HEAVY
IN INCH SIZES—LIGHT AND MEDIUM WITH TAPERED SLEEVE
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Manufacturers of precision ball and roller bearings since 1928

THE HOFFMANN MANUFACTURING CO. LTD., CHELMSFORD, ESSEX
TELEPHONE: 3151 (SEVEN LINES) TELEGRAMS: HOFFMANN, CHELMSFORD, TELEX

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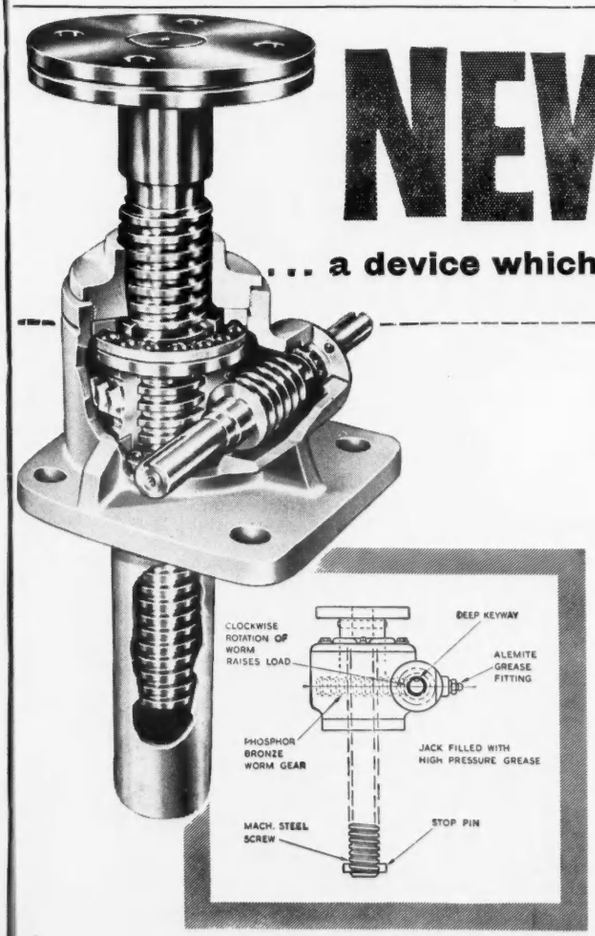

NEW TO BRITISH INDUSTRY

... a device which every machinery designer should know about

Duff-Norton worm gear jacks provide a purely mechanical means for accurate positioning of loads weighing as much as several hundred tons and maintaining them indefinitely without creep. Operating in any position, and functioning as components of machinery and equipment, they can raise and lower loads, apply pressure or resist impact. Jack capacities range from 5 to 100 tons.

When two or more jacks are connected by means of shafting and mitre gear boxes they lift in unison, even when the load is unevenly distributed. They are available with standard raises up to 25" and will provide exactly the same raise for years without adjustment. Worm gear jacks are suitable for operation at ambient temperatures up to 200°F.

Thousands of these jacks are in use in America on feeding tables, tube mills, welding positioners, pipe cut-off and threading machines, testing equipment, aircraft jigs, loading platforms, rolling mills conveyor lines, arbor presses, and numerous other types of equipment. If you have a positioning problem, write for catalogue giving complete information, drawings and full specifications.

Duff-Norton WORM GEAR Jacks

AVAILABLE FROM **Consolidated Pneumatic**

CONSOLIDATED PNEUMATIC TOOL CO. LTD · DAWES ROAD · LONDON · S.W.6
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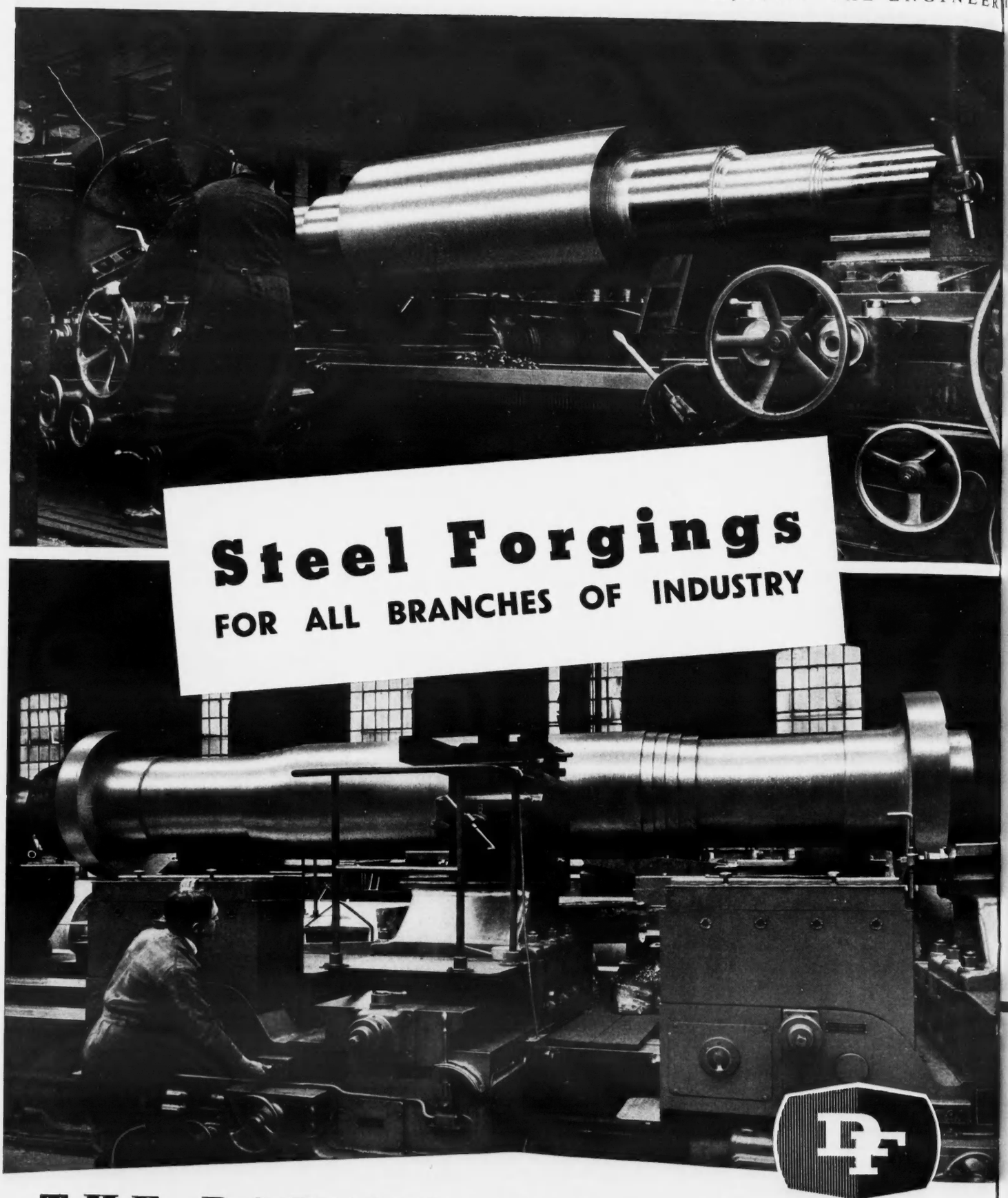

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No. 1071
G.M. Gate Valve

No. 1028B
Globe Steam Valve

No. 1031
G.M. Globe Valve

(Left) *To* B.S. 1952. *With flanged ends.*

(Centre) *Renewable stainless steel seat and valve, 300 p.s.i. Up to 600°F. The most reliable valve of its class ever produced.*

(Right) *With metal seat. Produced to* B.S. 2060.

Top value in steam valves -from Peglers

UP TO 'BS' AND BEYOND!

High quality—in workmanship, materials, valve design . . . This is a characteristic of *all* Peglers steam valves. Whilst most are produced to B.S. standards, some stock valves, such as the highly-advanced 1028B steam stop valve, actually go beyond B.S. requirements!

NEW Advanced Features:

Peglers improved non-heating handwheel
This 'ever-cool' wheel is now fitted as standard on all Peglers steam valves. Pleasant to grip. Red enamel finish.

Coded for rapid identification
Colour-coded identity discs are fitted at the centre of handwheels, indicating valve pressure and temperature ratings, and B.S. number.

ENGINEERS!

Send now for your copy of Peglers new 1960 Catalogue

When writing please state name of your Company and position you occupy

Peglers range includes: Copper Alloy Globe, Check and Gate Valves, as well as Radiator Valves and Unions — all to B.S. requirements.

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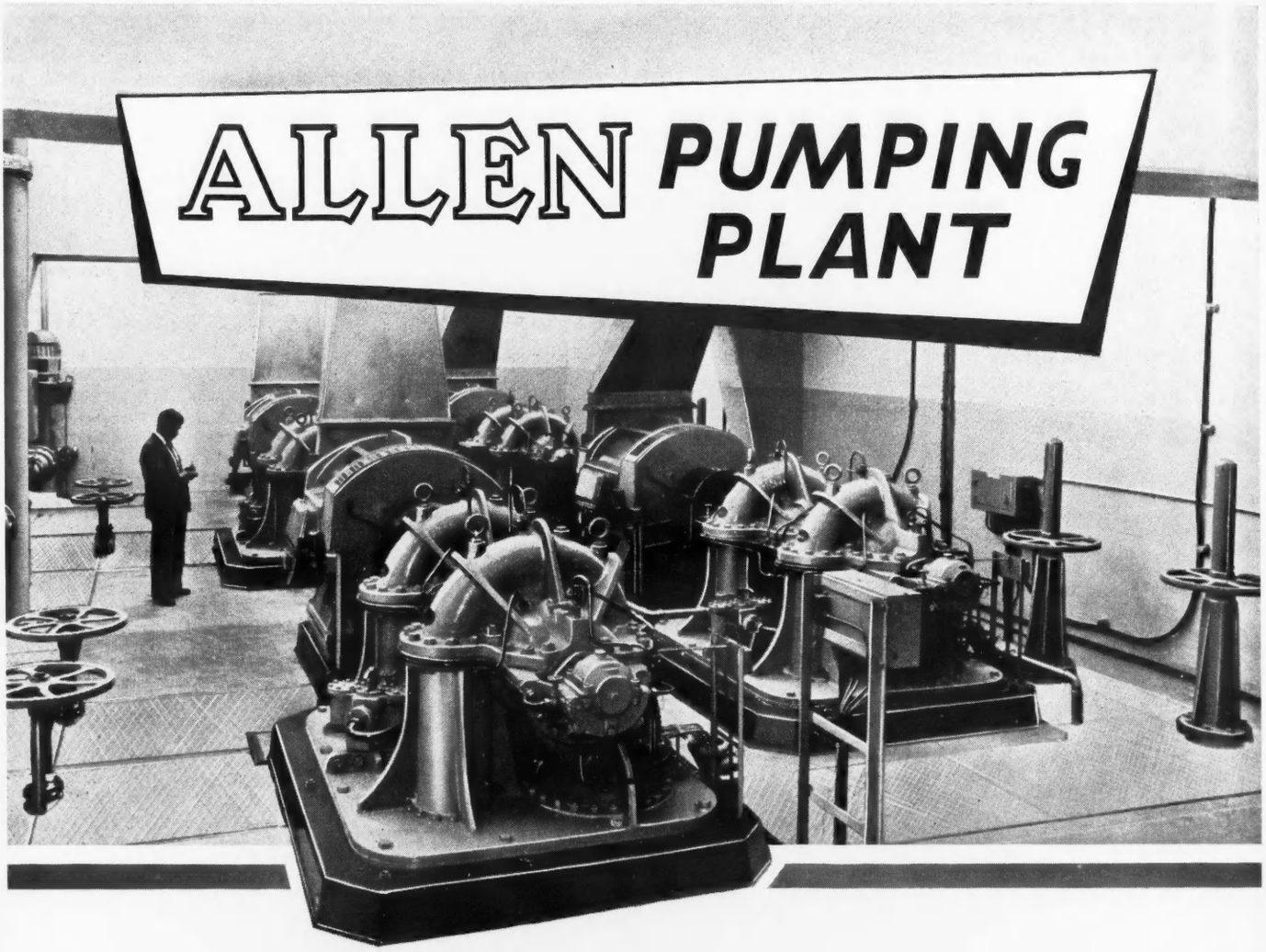

for Power Station service

The plant illustrated is in service for the Electricity Supply Commission's Highveld Power Station, Orange Free State, South Africa.
It comprises four Allen horizontal double-suction, two-stage pumps with 20/16-in. branches, driven by 1,245-h.p. M-V motors. Each pump is designed for a duty of 360,000 gallons per hour against a total head of 490 feet running at a speed of 1,485 r.p.m. These pumps are typical of a large number of ALLEN units installed for power station and waterworks service.

ALLEN centrifugal, axial- and mixed-flow pumps, horizontal or vertical, are designed to meet all requirements up to the largest capacity units needed in modern installations.

Specialists in complete Pumping Plant installations

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Telephone: Bedford 67400 *Telegrams:* Pump Bedford Telex (*Telex No. 82100*)

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Metcalfe's High Pressure Washing Plant

SUITABLE FOR ALL INDUSTRIAL APPLICATIONS

The "Metcalfe's" High Pressure Washing Plant provides the answer to the problem of cleaning in industry to-day. The plant is supplied on a suitable hand truck for portable use or it can be fitted as a permanent installation, and the only services required to operate it are :

(1) Water supply (static or mains). The consumption is 550 gallons per hour.

(2) Steam supply at any pressure above 60lbs. per square inch. The consumption is 700lbs. per hour.

The Washer is extremely simple to operate and can be easily operated in complete safety by unskilled personnel. The high temperature and pressure of the jet make it unequalled for power and efficiency and the use of cleaning solutions is not normally required.

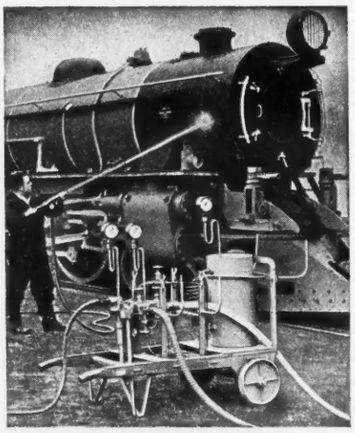
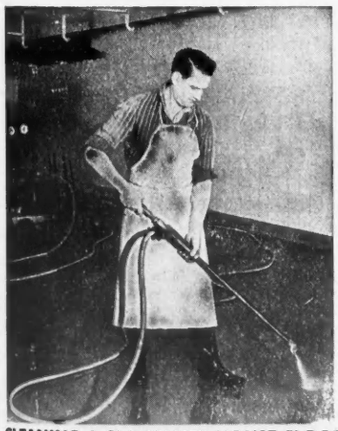


Photo by kind permission of the Vulcan Foundry Ltd

CLEANING A LOCOMOTIVE



CLEANING A SLAUGHTER-HOUSE FLOOR

ADVANTAGES OF THE 'D & M' SYSTEM OF WASHING

- (1) Delivers an extremely hot supply of water at a very high pressure thus ensuring the most efficient cleaning.
- (2) Ensures a great reduction in cleaning costs, due to the saving in man hours which is always found.
- (3) The injector is perfectly automatic and re-starting and requires no attention once the water valve has been set for the usual working pressures.
- (4) It will operate satisfactorily with low steam pressures (60lbs. per square inch upwards).
- (5) It can be operated with perfect safety and satisfaction by a non-skilled labourer.
- (6) Simple, compact and light.
- (7) No detergents or cleaning solutions are normally necessary.
- (8) No other system offers the same flexibility at low operating costs, low maintenance and low installation costs as the Metcalfe High Pressure Washing Plant.
- (9) A wide range of jet temperature and pressure is available so that the apparatus is suitable for all types of requirements.

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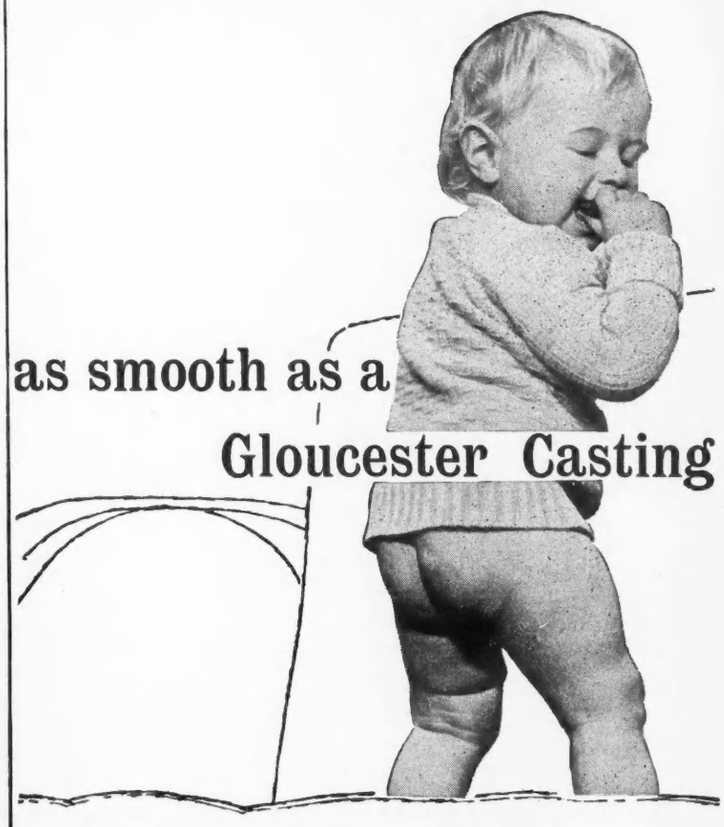


as smooth as a Gloucester Casting

The smoother and cleaner the casting the more accurately it fits into the machining jigs allowing saving of time during machining process.

At Gloucester, Malleable iron castings are as clean as modern science and machines can make them.

Superb core making equipment, careful analysis of sand at every stage of the core making and moulding processes, the use of special mould and core dressings, ensure clean castings, even as they leave the "knock out" bay for final fettling.

The elevator type electric-furnace anneals in 48 hours instead of the usual 7 days. It also allows greater control of the casting during annealing, resulting in uniformity of metal, greater strength, and — a smoother, finer skin.

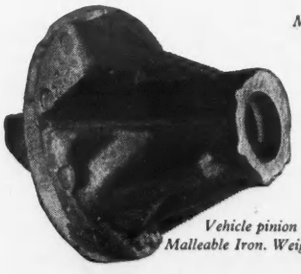
Gloucester can handle large runs of malleable castings for the automobile, railways, electrical and farming industries.

Gloucester are always willing to visit customers and help in the design of castings to save time and cost in production.

A typical Gloucester Malleable specification.

Gloucester Blackheart Malleable	*Gloucester Lamellar Pearlitic Malleable*
Elongation .. 18%	Elongation .. 5%
Yield Point .. 12 tons	Yield Point .. 24 tons
Tensile Strength 25 tons psi	Tensile Strength 35 tons psi

Spring mounting bracket in Malleable Iron Weight 8½ lbs.



Vehicle pinion housing in Malleable Iron. Weight 28 lbs.

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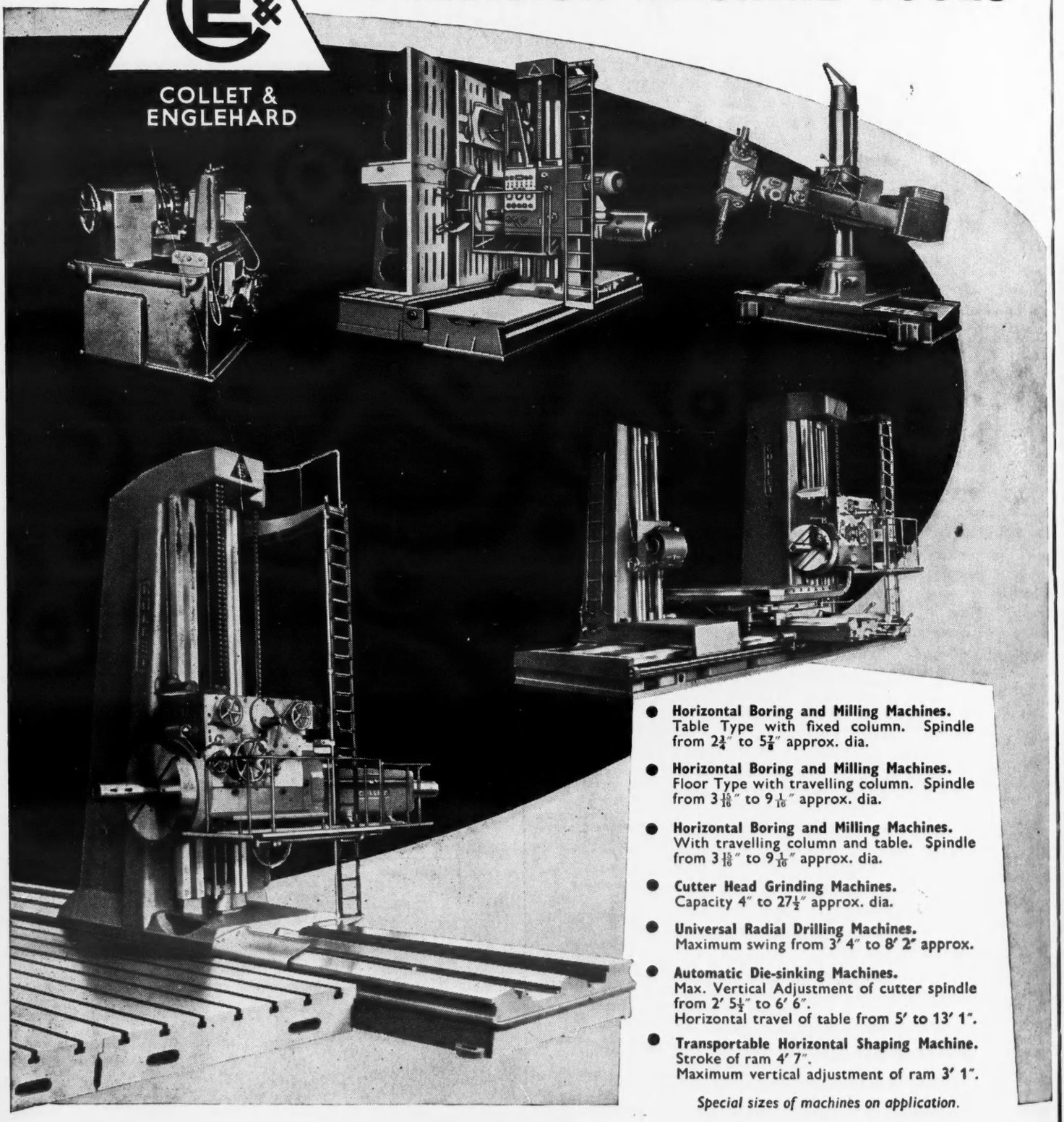
high production
PRECISION MACHINE TOOLS



- **Horizontal Boring and Milling Machines.** Table Type with fixed column. Spindle from 2¾″ to 5⅞″ approx. dia.
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- **Transportable Horizontal Shaping Machine.** Stroke of ram 4′ 7″. Maximum vertical adjustment of ram 3′ 1″.

Special sizes of machines on application.

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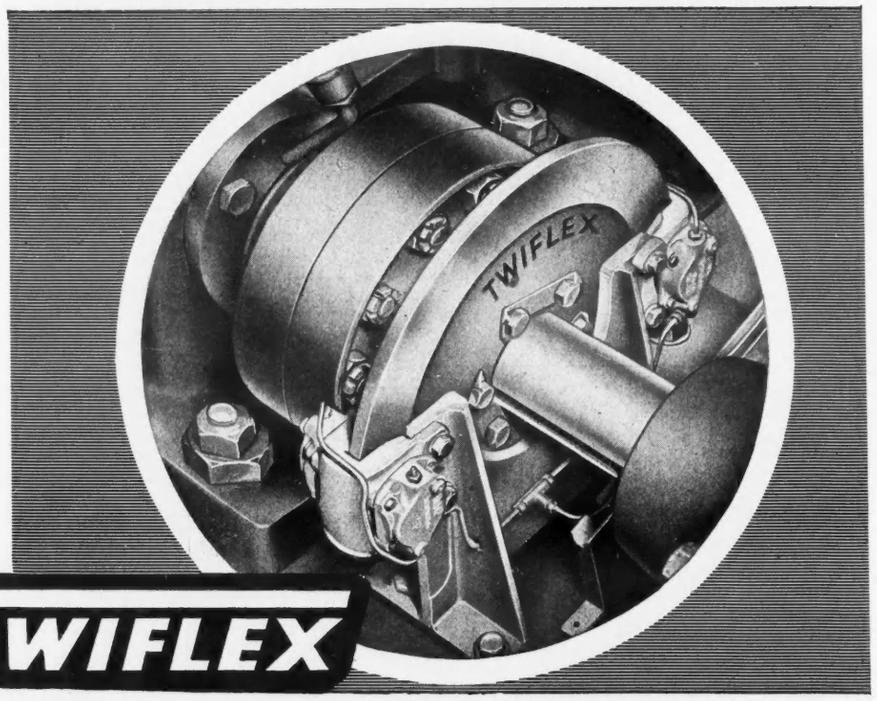
for greater STOPPING *power . . .*



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Heavy duty industrial disc brake with double Dunlop industrial calliper units

industrial DISC brakes!

(INCORPORATING DUNLOP CALLIPER UNITS)

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This revolutionary system is now available for industry and Twiflex Industrial Disc Brakes are setting new standards—wherever effective control means the greatest use of available power resources.

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Twiflex Industrial Disc Brakes are superior to existing braking methods *in every way* because they give you . . .

- **Maximum efficiency under all conditions.**
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- **Complete absence of "brake fade"**
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TWIFLEX COUPLINGS LIMITED (*One of the Sheepbridge Engineering Group*)
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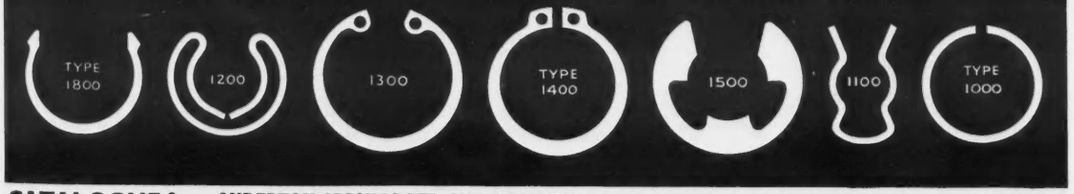

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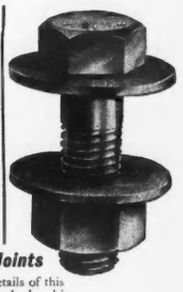
FRICTION GRIP BOLTS
for Structural Joints



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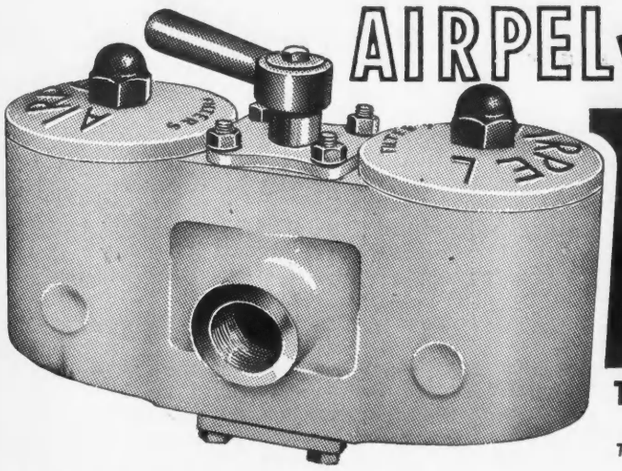

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★ LARGE CAPACITIES ★ LOWEST PRESSURE DROP
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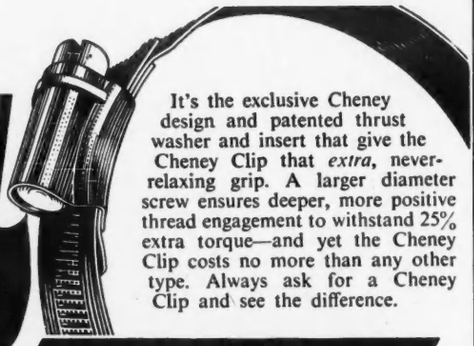
Always fit
Cheney
the clip with the double grip



It's the exclusive Cheney design and patented thrust washer and insert that give the Cheney Clip that *extra*, never-relaxing grip. A larger diameter screw ensures deeper, more positive thread engagement to withstand 25% extra torque—and yet the Cheney Clip costs no more than any other type. Always ask for a Cheney Clip and see the difference.

CHENEY WORM DRIVE CLIP from FENTER

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BAG CLOTHS	LABEL AND INDICATOR CLOTHS
FILTER CLOTHS	CUT SHAPES TO ORDER
NARROW ROLLS	CONVERSIONS TO YOUR REQUIREMENTS
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The guiding hand with a giant's strength

and more than human accuracy, timing and speed—that's 'Pneutomation', the pneumatic power system that controls a host of simple or complex operations, from jig-boring to bell-ringing. Take a look round *your* factory, you'll find a score of jobs that could do with a 'pick-me-up' from 'Pneutomation'. 'Pneutomation' costs less than you'd think too, because systems to suit almost every need are available 'off-the-shelf', thanks to the very wide range of standard components.

Squinch says:
"Plan with Lang Pneutomation in mind, right from the start, you'll be certain of the happy ending!"

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Lang Pneumatic Ltd

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P4283

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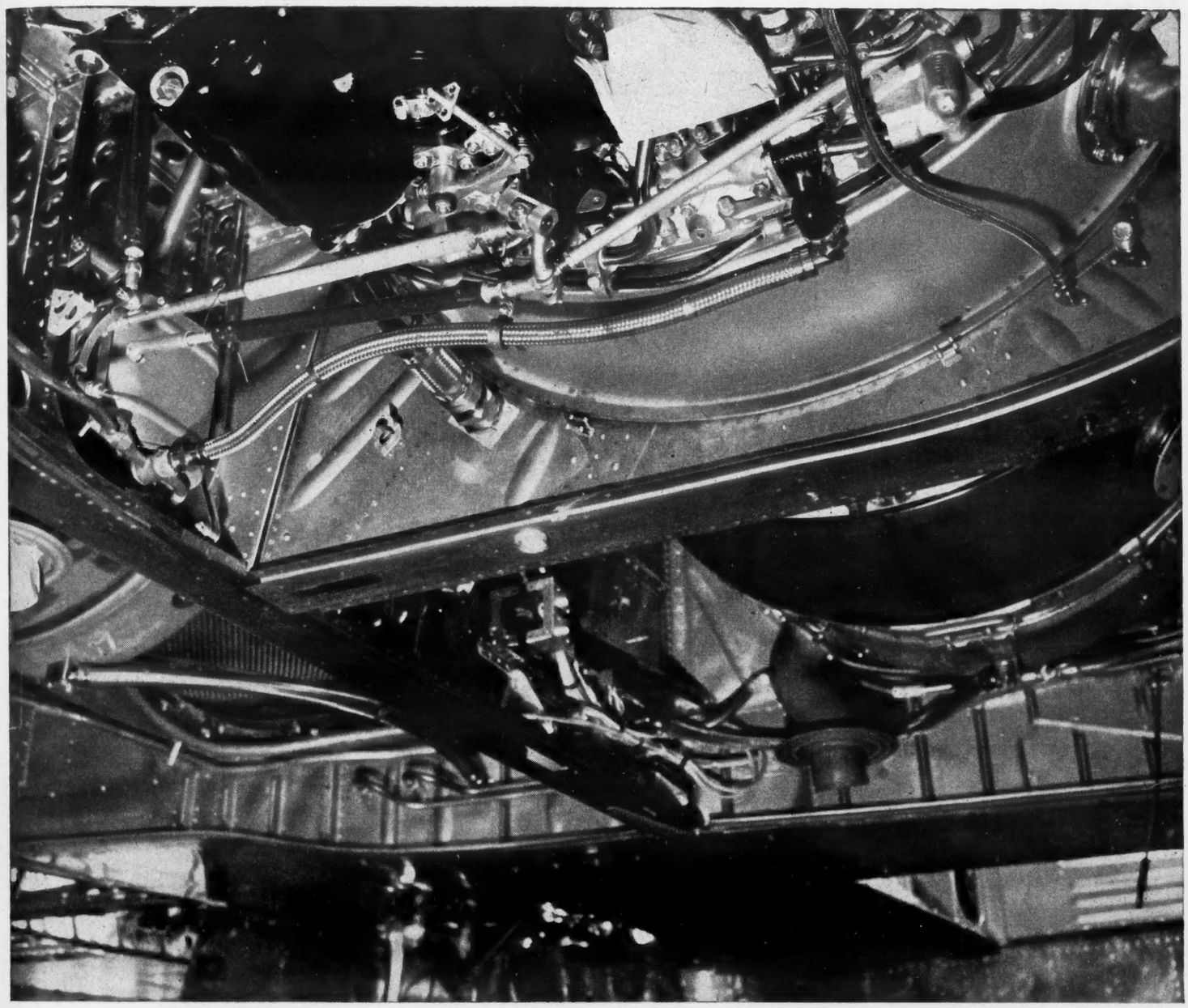
'FLUON' INCREASES PRODUCTION EFFICIENCY IN INDUSTRY



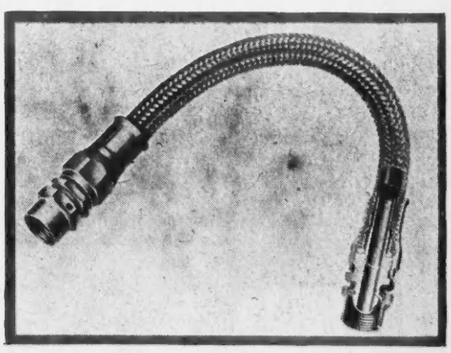
'Fluoroflex' Flexible Pipes lined with tubing made from 'Fluon' CD 1 in the de Havilland Comet

'Fluon' CD 1 is used in 'Fluoroflex' Pipes chosen for the Comet

As a flexible hose lining material 'Fluon' CD 1 is pre-eminent.

- Its flexural fatigue characteristics are exceptional.
- The only chemicals which attack it are molten alkali metals and a few fluorine compounds at high temperature and pressure.
- It can be used continuously at temperatures up to 250°C., and retains its tough, flexible nature down to at least liquid nitrogen temperatures.
- Its weathering characteristics are excellent and it has an indefinite shelf life.

These are among the many reasons why Palmer 'Fluoroflex' Flexible Pipes lined with tube made from 'Fluon' CD 1 are being fitted by The de Havilland Aircraft Company Limited to Comet aircraft. Tests carried out on these pipes correspond to 10,000 hr. life on the hydraulic system of the Comet 4 B.



'Fluoroflex' Flexible Pipe made by Palmer Aero Products Ltd., London, N.W.8, lined with tubing made from 'Fluon' CD 1 p.t.f.e.

'FLUON'

'Fluon' is the registered trade mark for the polytetrafluoroethylene manufactured by I.C.I.

IMPERIAL CHEMICAL INDUSTRIES LIMITED · LONDON · S.W.1

PT44

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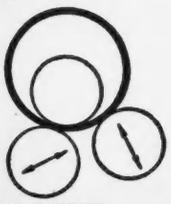
BRONX

PLATE BENDING ROLLS

Illustrated is a Bronx 8′ × ¾″ capacity machine, installed at Messrs. Carrier Engineering Co.



Bronx Plate Bending Rolls reduce costs on batch and mass production work as well as on accurate "one off" cylinder jobs.

Every machine is supplied with a capacity chart giving widths, thicknesses and diameter capacities. This information is essential to your Estimating Dept., as well as the operator on the machine.

There is a wide range of massively built Bronx Plate Bending Rolls to give consistent accuracy with thinnest to thickest steel plates up to 40 ft. in width, and standard machines cope perfectly with conical work.

There are also Bronx Press Brakes, Tube Straightening Machines, Bar Reeling Machines, Roller Levellers, etc. Write for Catalogues.

TEL.: LYE 2307/8

BRONX ENGINEERING CO. LTD., LYE, WORCS.

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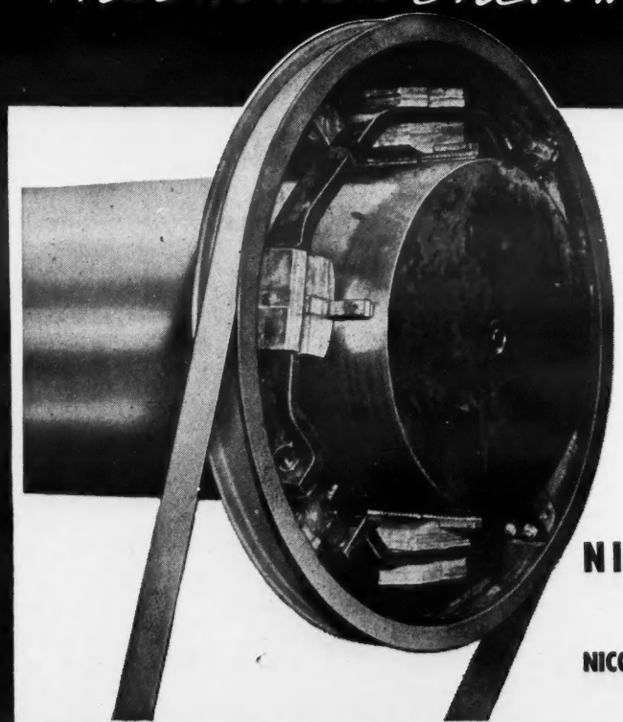
PRODUCTION & REPAIR

MASTER-HONE EQUIPMENT *gives* **ACCURACY & SUPERFINISH**



Patented Master-Hone equipment gives a higher standard of accuracy combined with micro-inch surface finish than any other method. In shaft production and repair it will improve quality and cut down operating time and costs.

Master-Hones are available in a range of sizes from 4" to 24" dia.

Repair work undertaken on contract for these and larger sizes.

Please write for literature.

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NICOL & ANDREW (LONDON) LTD. 188 Uxbridge Road, Hanwell London, W.7.
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There are reduced rates (i.e., not on a pro rata basis) for advertisements of ¼-page (12 column inches) and upwards, e.g., ¼-page £25 10s. ½-page £48. Full page £90.

Run-On and Semi-Displayed Styles. Both these styles are available for single column width advertisements of any depth up to 12 inches.

Displayed and Illustrated Styles. The minimum size for a Displayed advertisement is 3 inches single column, for an illustrated advertisement it is a ¼-page (12 column inches). Thereafter the sizes for both progress in steps 3 inches deep across 1, 2, 3 or 4 columns.

Use of Box Number. 2/- which includes forwarding of replies.

Copy Dates. Tuesday for publication on Friday of the same week. If proofs are wanted, copy is required on Thursday for publication on Friday of the following week.

Advertisements for publication should be addressed to:—**Classified Advertisement Dept., "THE ENGINEER," 28 Essex Street, Strand, London, W.C.2**

Urgent advertisements may be telephoned to CENtral 6565.

PUBLIC APPOINTMENTS

CITY OF LIVERPOOL EDUCATION COMMITTEE

COLLEGE OF TECHNOLOGY

BYROM STREET, LIVERPOOL, 3

Principal : S. A. J. PARSONS, B.Sc.(Econ.)., M.I.Mech.E., M.I.Prod.E., M.B.I.M.

DEPARTMENT OF ELECTRICAL ENGINEERING

Applications are invited for the appointment of HEAD of the Department (Grade III). Duties to commence as soon as possible after 1st September, 1960. Salary: £1800 by £50 to £1950 per annum. Applicants must have good teaching, industrial and/or research experience and should possess high academic qualifications.

The person appointed will be expected to develop further the Advanced Courses and Post-Graduate Courses and to encourage research. Work will begin shortly on a building which includes completely new accommodation, laboratories and workshops for the department.

Further particulars and application form (returnable by 28th September, 1960) from H. S. Magnay, M.A., Director of Education, 14 Sir Thomas Street, Liverpool, 1.

THOMAS ALKER,
Town Clerk and Clerk to the Local Education Authority.

(J.6313) E5498

NORTH EAST DERBYSHIRE JOINT WATER COMMITTEE

TECHNICAL STAFF

Applications are invited for the following appointment on the staff of the Engineer and Manager.

The commencing salary will be in accordance with qualifications and experience.

The appointment offers good experience in waterworks design and construction.

SENIOR ASSISTANT ENGINEER (A.P.T. Grade IV £1065-£1220).

Applicants must be Corporate Members of the Institution of Civil Engineers and they should have had previous experience in the design and construction of service reservoirs, treatment plants and pumping stations.

Housing accommodation will be made available to the successful applicant and a car allowance will be paid up to 8 H.P. in accordance with the National Scale. Removal expenses paid.

The post is superannuable and the successful applicant will be required to pass a medical examination.

Applications stating age, qualifications, experience and appointments held together with the names of two referees should be submitted to the undersigned not later than 20th August, 1960.

H. O. HAWKINS, Clerk.

Rural Council House, Saltergate, Chesterfield. E5503

CITY OF SHEFFIELD

WATERWORKS UNDERTAKING

APPOINTMENT OF TECHNICAL ASSISTANT

Applications are invited for the above appointment (Special Classes Grade £785 to £1070) on the permanent staff of the Waterworks General Manager and Engineer (A. B. Baldwin, M.Eng.). Commencing salary according to qualifications, ability and experience.

Applicants must be University Graduates or have passed parts I and II of the examination of the Institution of Civil Engineers and in each case to have had at least five years' experience (including the period spent on theoretical training.).

The post is superannuable and the successful applicant will be required to pass a medical examination.

Applications, stating age, education and training, qualifications, present and past appointments (with dates and salaries) and quoting the names and addresses of two referees, should reach the undersigned not later than 8th August, 1960.

JOHN HEYS, Town Clerk.

Town Hall, Sheffield, 1. E5516

PUBLIC APPOINTMENTS

UNIVERSITY OF NOTTINGHAM

LECTURESHIP IN CHEMICAL ENGINEERING

Applications are invited for a LECTURESHIP IN CHEMICAL ENGINEERING. Candidates should have an honours degree in Chemical Engineering or corporate membership of the Institution of Chemical Engineers, with experience in research and in the operation and supervision of full-scale chemical plant. Salary scale £950 to £1475 (efficiency bar) to £1850. Conditions of appointment and form of application, which should be returned as soon as possible, from the Registrar. E5478

BARNSLEY CORPORATION WATER DEPARTMENT

APPOINTMENT OF ENGINEERING STAFF

There is a vacancy in the establishment for :

(1) ASSISTANT ENGINEER, Grade A.P.T. IV.

Additionally the following temporary appointments are to be made in connection with new works :

(2) ASSISTANT ENGINEER, Grade A.P.T. IV.

(3) ASSISTANT ENGINEER, Special Classes.

(4) ENGINEERING ASSISTANT, A.P.T. I/Special Classes.

The commencing salary for the appointments on A.P.T. Grades may be at any point below the maximum, and on Special Scales up to two points below the maximum, according to qualifications and experience.

For Posts (1), (2) and (3) applicants should be Chartered Civil Engineers and desirably Corporate Members of the Institution of Water Engineers or have experience in Water Engineering.

For Post (4) applicants should be Engineering Graduates or be otherwise qualified to be placed on Grade A.P.T. I within the terms of the Scheme of Conditions of Service for Local Government Administrative, Professional and Technical Services.

The persons appointed will be required to work on the design and execution of new works of supply entailing an estimated capital expenditure of some £750,000 within the next five years, and involving reinforced and prestressed concrete structures and pumping installations and pipe lines.

The appointments will be subject to (a) the Scheme of Conditions of Service for A.P.T.C. Staff : (b) any other General Conditions of Employment in operation within the Corporation from time to time : and (c) one month's notice on either side.

An essential user's car allowance is normally paid to the holder of Post (1).

The appointments will also be subject to the Local Government Superannuation Acts, for which purpose the successful candidates will be required to pass a medical examination.

Housing accommodation can be provided if necessary and 50 per cent of removal transport expenses will be paid in approved cases.

Further details of the undertaking and works programme and of the appointments may be obtained from W. Gordon Lees, Waterworks Engineer and Manager, Waterworks Office, Town Hall, Barnsley.

A. E. GILFILLAN, Town Clerk.

Town Hall, Barnsley. E5487

CITY AND COUNTY OF BRISTOL

CITY ENGINEER AND PLANNING OFFICER'S DEPARTMENT

APPOINTMENT OF PLANT SUPERVISOR

Applications invited for post of MECHANICAL PLANT SUPERVISOR. Salary : Grade A.P.T. III (£880 to £1065 p.a.).

Successful applicant will be required to take charge of maintenance and management of the plant operated by the Department, which includes excavators, bulldozers, road rollers, tractors, compressors and general civil engineering plant.

Post pensionable : medical examination and, except in case of an officer transferred from service of another Local Government Authority, probationary period of six months.

Applications stating age, nationality, educational training, qualifications (if any), present and previous positions with salaries and dates, notice required to terminate present appointment, whether related to a member or senior officer of the Council and names of two referees, to City Engineer and Planning Officer, Cabot House, Deanery Rd., Bristol 1, by 22nd August.

Canvassing disqualifies. E5515

PUBLIC APPOINTMENTS

CITY OF SHEFFIELD

WATERWORKS UNDERTAKING

YORKSHIRE DERWENT SCHEME

ASSISTANT ENGINEERS

ASSISTANT ENGINEERS—APT Grade IV (£1065-£1270).

Applications are invited from Chartered Engineers for these appointments which will be subject to National Joint Council conditions as applied by the City Council and to the passing of a medical examination.

Commencing salary within the grade according to qualifications and experience. Consideration will be given if required to assistance with housing accommodation and removal expenses in suitable cases.

Candidates should preferably have had experience of the design and construction of such civil engineering works as are comprised by major schemes of water supply. Further details of the Yorkshire Derwent scheme and of these appointments, can be obtained from A. B. Baldwin, Esq., M.Eng., General Manager and Engineer, Sheffield Corporation Waterworks, Town Hall, Sheffield, 1.

Applications are to be forwarded to the undersigned by 8th August, 1960, stating age, qualifications, past and present appointments (with dates and salaries), details of relevant experience and schemes engaged upon, together with the names of two referees.

JOHN HEYS, Town Clerk.

Town Hall, Sheffield, 1. E5517

THE BRITISH SHIPBUILDING RESEARCH ASSOCIATION

ATOMIC ENERGY SECTION

The British Shipbuilding Research Association has vacancies in its Atomic Energy Section for men aged about 25 with a good University Degree in marine or mechanical engineering and with practical training and experience. Research experience an advantage. The persons appointed will be required in the first instance to work in the Association's team at Winfrith, Dorset, studying the possible application of nuclear power to merchant ship propulsion. Experience of nuclear energy is not an essential qualification as training in this will be given. The commencing salaries will depend upon age and qualifications and the appointments are subject to the Federated Superannuation System for Universities.

Applications with full particulars should be addressed to : B.S.R.A., 5 Chesterfield Gardens, Curzon Street, London, W.1, quoting reference JER. E5523

THE REPUBLIC OF THE SUDAN

SHIFT CHARGE ENGINEER

Applications are invited from those suitably qualified to fill a vacancy of SHIFT CHARGE ENGINEER in the Central Electricity and Water Administration, Sudan.

Candidates should have a sound technical training and have had experience in modern steam power stations operating at pressures of 500 lb per square inch with oil-fired boilers. A knowledge of diesel engine operation would be an advantage. The selected candidate will be expected to carry out maintenance work on the generating plant if required.

The appointment will be on contract for three years, the first year being probationary.

Salary will be in the range of £S.1100 to £S.1670, and the starting point will be fixed according to age, qualifications and experience. In addition to the salary, a cost-of-living allowance is payable (£S.187 per annum), and an initial outfit grant of £S.50 on appointment. (£S.1 equals £1 0s. 6d.) There is no income tax payable in the Sudan.

In addition accommodation will be provided at a rental not exceeding 7½ per cent of the basic salary. Hard furnishings are available at a nominal rent. Liberal leave on full pay with full passage paid for the Official, Wife and children up to the age of 18 granted after 18 months' service.

Application should be made in writing in the first instance, giving full details of age, qualifications, experience, and with copies of two recent testimonials, to the Appointments Section, the Sudan Embassy, Cleveland Row, St. James's, London, S.W.1, quoting reference 4/3203.

Closing date 15th August, 1960. E5486

PUBLIC APPOINTMENTS

DEPARTMENT OF GOVERNMENT ELECTRICAL UNDERTAKINGS

CEYLON

POST OF DEPUTY CHIEF RESIDENT ENGINEER, HYDROELECTRIC SCHEME

STAGE IIB

Applications are invited for the post of DEPUTY CHIEF RESIDENT ENGINEER to be mainly in charge of Tunnel construction of the above scheme. The appointment will be for a period of three years.

2. The salary of the post is £2800 to £3200 per annum, according to experience of the candidate selected which will be paid at the current rate of exchange.

3. Applicants who will be required to furnish a Medical Certificate as to their physical fitness for service in Ceylon must be a Corporate Member of the Institute of Civil Engineers with extensive experience as Resident on long lined rock Tunnel construction.

4. The Ceylon Government will contribute 7½ per cent of salary to a Provident Fund. Free passages to the Island and back will be provided for the successful applicant and his family up to a maximum of four persons besides the applicant. Rent Allowance, if not in occupation of Government quarters, and cost of living allowance are payable in terms of Government Regulations in force at the time.

5. A copy of the letter of appointment could be inspected at the office of the Ceylon Government Representative.

6. Applications giving full details of experience should be submitted within 14 days in triplicate with three copies of testimonials to Messrs. Preece, Cardew and Rider, 8, 10 and 12, Queen Anne's Gate, Westminster, London, S.W.1.

E5469

EAST ANGLICAN REGIONAL HOSPITAL BOARD

REGIONAL ENGINEER'S DEPARTMENT

APPOINTMENTS

(1) ENGINEERS, GENERAL GRADE (MECHANICAL)

(a) Corporate members Inst.Mech.E.: Salary £1160 to £1600.

(b) Associate members Inst. H. & V.E.: Salary £910 to £1400.

(c) Graduate members Inst.Mech.E.: Salary £910 to £1205.

(2) ENGINEERS, GENERAL GRADE (ELECTRICAL)

Graduate members Inst. E.E.: Salary £910 to £1205.

Candidates appointed will be engaged on design of central heating and hot water systems, air conditioning equipment, &c., including design of steam boiler plant, laundry installations OR electric lighting and power installations, radio and telephone installations and electronics in relation to hospital engineering projects. Experience in estimating and in the preparation of specifications desirable.

Candidates appointed under (1) (a) or (b) will be responsible for a small design team for all aspects of mechanical engineering services in large hospital building projects.

(3) ENGINEERING DRAUGHTSMEN (MECHANICAL AND ELECTRICAL)

(i) Salary £1030 to £1250.

(ii) Salary £870 to £1010.

(iii) Salary £550 to £850.

Candidates for (i) and (ii) should have H.N.C. or O.N.C. and be experienced in the design of engineering works and the preparation of tender drawings and specifications under supervision.

Candidates for (iii) should have had three years practical and theoretical training including site or workshop experience with suitable technical experience in engineering drawing.

Applications, stating age, qualifications, experience and details of present position, with names of three referees to Secretary of Board, 117 Chesterton Road, Cambridge, by 31st August, 1960. E5423

Classified Advts. continued on page 90

PUBLIC APPOINTMENTS

THE UNITED BIRMINGHAM HOSPITALS

DEPUTY SUPERINTENDENT ENGINEER

Applications are invited for the appointment of DEPUTY SUPERINTENDENT ENGINEER to these hospitals.

The successful candidate will be responsible to the Superintendent Engineer and will, as deputy, be subject to those duties and responsibilities set out in Whitley Council Circular P.T.B.51 for a Superintendent Engineer.

His duties will include responsibility to the Superintendent Engineer for the supervision of the engineering services and general maintenance of the Queen Elizabeth Hospital. Some experience in building construction and works maintenance would be an advantage.

Applicants should preferably be corporate members of the Institute of Mechanical Engineers or the Institute of Electrical Engineers or hold an equivalent professional qualification, but must in any event conform to requirements as to qualification laid down in Whitley Council Circular P.T.B.91 for Superintendent Engineers. This is a new appointment and salary will be on the scale £1000 by £30 (4) by £35 (1) to £1155. A house will be available, if required, upon terms to be agreed. Further information may be had, if needed, from the Secretary to the Board of Governors, Queen Elizabeth Hospital, Birmingham, 15, to whom applications including names of three referees should be submitted by 24th August, 1960.

E5490

CITY OF LINCOLN WATER DEPARTMENT

ASSISTANT ENGINEER

Applications for the post of ASSISTANT ENGINEER, in the Special Grade (£785-£1070), are invited from candidates who have a degree in Civil Engineering or who have passed parts I and II of the Examination of the Institution of Civil Engineers.

The commencing salary will be related to the experience of the candidate.

The post is superannuable and a medical examination will be required.

Car allowance will be paid and housing accommodation may be available if required.

Applications, accompanied by the names of two referees, should reach me by the 20th August, 1960.

Re-grouping of the Water Undertakings in the area is in active progress and opportunities for promotion are likely in the case of a suitable engineer.

J. HARPER SMITH,
Town Clerk.

Town Clerk's Office,
Lincoln.
21st July, 1960.

E5506

TENDERS

THE REPUBLIC OF THE SUDAN

MINISTRY OF IRRIGATION AND HYDRO-ELECTRIC POWER

KHASM EL GIRBA DAM AND ASSOCIATED WORKS

The Ministry of Irrigation and Hydro-Electric Power of the Republic of the Sudan propose to call for TENDERS for the Main Civil Engineering and Associated Works of the KHASM EL GIRBA Dam Scheme in the gorge of Khasm El Girba on the Atbara. The site is about 4 kilometres upstream from the town of Khasm El Girba, approximately 437 kilometres from the junction with the main Nile.

The Main Civil Engineering Works will comprise the construction of a buttress concrete dam across the river channel, with earth dams on either flanks, together with control gates and other equipment. The concrete dam will have a length of 350 metres and a maximum height of 55 metres above river bed level. The length of the earth embankments will be approximately 3·5 kilometres.

The Associated Works will comprise the construction of permanent and temporary housing with roads and services.

MAIN CIVIL AND ASSOCIATED ENGINEERING WORKS :

(1) A preliminary pamphlet showing drawings outlining the work involved will be available for issue now.

The general technical information in connection with the proposed works is indicated in the pamphlet.

(2) Contractors who may be interested in tendering for the Main Dam and Associated Works should submit full details of their qualifications and experience as soon as possible and not later than July 31st, 1960, to enable Tender documents and drawings to be issued on August 10th, 1960, to those Contractors who satisfy the requirements of the Ministry.

ALTHOUGH THE GOVERNMENT OF THE REPUBLIC OF THE SUDAN IS NOT YET ABLE TO ENTER INTO ANY DEFINITE COMMITMENT, IT IS HOPED THAT THE MAIN CIVIL ENGINEERING WORKS WILL COMMENCE IN NOVEMBER, 1960.

The Consulting Engineers to the Ministry on this Project are :

S.O.G.R.E.A.H.,
Societe Grenobloise d'Etudes et d'Applications Hydrauliques,
Boite Postale 145,
GRENOBLE (FRANCE).

Applications for the preliminary pamphlet by bona fide firms should be made to one of the following, with a copy to the Consulting Engineers :

The Ministry of Irrigation and Hydro-Electric Power,
The Republic of the Sudan, P.O.B. No. 878,
KHARTOUM (THE SUDAN).

The Director, Ministry of Irrigation and Hydro-Electric Power,
The Republic of the Sudan,
WAD MEDANI (The Sudan).

Applications received after the dates specified above might not be considered.

E5521

PUBLIC APPOINTMENTS

THE BRITISH SHIPBUILDING RESEARCH ASSOCIATION

MARINE ENGINEERING SECTION

The British Shipbuilding Research Association has vacancies in the following two Grades in its Marine Engineering Section :

(a) GRADE B—This Grade includes persons who have been assessed as having the ability to initiate, lead and execute research. Qualifications required are a good University Degree in marine or mechanical engineering and with practical training and experience. Research experience and/or service at sea an advantage. The salary will be within the range of £800 to £1600 per annum.

(b) GRADE C—The staff in this Grade are concerned with the conduct of the experimental side of investigations. Qualifications required are a Degree in marine or mechanical engineering, Higher National Certificate or equivalent qualifications. Apprenticeship or practical experience in engineering. Research and/or sea going experience an advantage. The salary will be within the range of £725 to £1350 per annum.

The commencing salary for each appointment will, however, depend upon age and qualifications. All appointments are subject to the Federated Superannuation System for Universities.

Applications with full particulars should be addressed to B.S.R.A., 5 Chesterfield Gardens, Curzon Street, London, W.1.

E5522

TENDERS

THE TEES VALLEY AND CLEVELAND WATER BOARD

BALDERHEAD IMPOUNDING RESERVOIR

Contract documents are now being prepared by the Board's Consulting Engineers, Messrs. Edward Sandeman, Kennard and Partners, of Westminster, for the construction at Balderhead on the River Balder, near Romaldkirk, North Riding of Yorkshire, of an earth reservoir embankment approximately 155 feet high and 3000 feet long at the crest, containing approximately 2,300,000 cy. yd. of fill. The concrete cut-off trench is expected to reach a depth of 100 feet or thereabouts, and its volume wil be approximately 50,000 cu. yd.

The ancillary works will include 14 feet internal diameter tunnels, bellmouth overflow shaft, valve shaft, etc.

The Board proposes to invite TENDERS for the CONSTRUCTION of this reservoir from selected Contractors. Contractors wishing to be considered for inclusion in the list of those invited to tender should therefore apply to the undersigned in writing not later than the 1st September, 1960.

Applicants must indicate what recent works of a similar nature they have carried out, giving the approximate costs and the names of Engineers to whom reference may be made. Applicants must also state their financial capacity to carry out the work.

Construction is anticipated to commence in the Spring of 1961.

E. A. MORRIS,
Clerk of the Board and Chief Executive Officer.

G.P.O. Box No. 60,
Water Board Offices,
Corporation Road,
Middlesbrough.

E5473

SUPPLIES AND DISPOSALS

N.I.C. BUILDING, PARLIAMENT STREET, NEW DELHI, INDIA

D.G.S. & D. TENDER ENQUIRY PROJECT/SE/2025 TO 27, 32, 85 AND 87 L/III

The office of the Directorate General of Supplies and Disposals, N.I.C. Building, Parliament Street, New Delhi, India, invites TENDERS for the following :

D.G.S. & D. TENDER ENQUIRY PROJECT/SE/2025 TO 27, 32, 85 AND 87-L/III

For the SUPPLY of SKID MOUNTED DIAMOND CORE DRILLS (Diesel Driven), Hydraulic Feed, with individual capacity 4000, 3000, 2000 and 1000ft. AX size, complete with accessories and pumping sets. Quantity required 26 sets. Together with boring and sinking apparatus and Tools.

Specifications, drawings etc., relative to the above, can be obtained from the Co-ordination Branch, India Store Department, Bromyard Avenue, Acton W.3, at a cost of 15 shillings per Tender and is not refundable. Tenders are to be returned to The Directorate General of Supplies & Disposals, N.I.C. Buildings, Parliament Street, New Delhi, India, so as to reach them by 6th September 1960.

Specimen copy of the above enquiry can be seen at India Stores Department, Engineering Branch, Bromyard Avenue, Acton, W.3 under the following reference : S.3420/60/NSC/ENG.2.

E5510

EDUCATIONAL

A.M.I.MECH.E., B.SC., City and Guilds, &c. Guarantee Postal Courses for all Exams. and Technical Divisions from Elementary to Degree standard including Automation Techniques. Approximately 95 per cent. successes. 148-page, prospectus, free on request.—B.I.E.T. (Dept. 22), 29, Wright's Lane, London, W.8. E114 E

EDUCATIONAL

MIDDLESEX COUNTY COUNCIL EDUCATION COMMITTEE

HENDON TECHNICAL COLLEGE

THE BURROUGHS, HENDON, LONDON, N.W.4.

DEPARTMENTS OF MECHANICAL AND ELECTRICAL ENGINEERING

PROGRAMME OF LECTURE COURSES TO BE GIVEN BY SPECIALISTS IN THE FOLLOWING SUBJECTS

1. MATHEMATICS FOR ENGINEERS—1. Six Lectures, commencing 26th September 1960.

2. MECHANICAL VIBRATIONS. Twelve Lectures, commencing 26th September, 1960.

3. TRANSISTORS AND THEIR APPLICATIONS. Twelve Lectures, commencing 27th September, 1960.

4. APPLICATIONS OF RADIO ISOTOPES IN INDUSTRY. Six Lectures, commencing 27th September, 1960.

5. MODERN MAGNETIC MATERIALS—1. Six Lectures, commencing 29th September, 1960.

6. MATHEMATICS FOR ENGINEERS—2. Six Lectures, commencing 7th November, 1960.

7. ANALYSIS OF INDETERMINATE STRUCTURES. Six Lectures, commencing 8th November, 1960.

8. ELECTRONICS FOR MECHANICAL AND CHEMICAL ENGINEERS. Six Lectures, commencing 9th November, 1960.

9. MODERN MAGNETIC MATERIALS —2. (FERRITES) Six Lectures, commencing 10th November, 1960.

The above lectures are intended for Graduates or Higher National Certificate Holders.

Fees : 10s. for a course of six Lectures. £1 for a course of twelve Lectures.

The Head of the appropriate department will be pleased to supply further particulars and reservation forms.

E5509 E

WELSH COLLEGE OF ADVANCED TECHNOLOGY

CATHAYS PARK, CARDIFF

ELECTRICAL ENGINEERING DEPARTMENT

FULL-TIME COURSE FOR PART III OF THE I.E.E. EXAMINATION

A full-time course in preparation for Part III of the Institution of Electrical Engineers' Examination will commence on October 31st, 1960. Applicants for admission to the course must have passed, or obtained exemption from, Parts I and II. Further particulars may be obtained from the Head of the Electrical Engineering Department at the College.

ROBERT E. PRESSWOOD,
Clerk to the Governors.

City Hall,
Cardiff.

E5505 E

NATIONAL COLLEGE OF RUBBER TECHNOLOGY

NORTHERN POLYTECHNIC, Holloway Road, London, N.7 *Tel:* NORth 4231

Head: F. H. COTTON, Ph.D., M.Sc., F.R.I.C., F.I.R.I.

'Rubber in Engineering'

(Organiser: F. R. SABERTON, A.M.I.Mech.E)

A course of six evening lectures by specialists from the College Staff, Research Associations and Industry, on Wednesday evenings commencing on 28th September, 1960 at 6.0 p.m.

Fee: £1. 2s. 0d.

Details and form of application from the Head of the College.

E5497 E

SITUATIONS VACANT

APPLICANTS ARE ADVISED TO SEND COPIES NOT ORIGINALS OF THEIR TESTIMONIALS UNLESS OTHERWISE REQUESTED.

A SMALL BUT SUBSTANTIAL FIRM of electro-mechanical engineers in the Hounslow area wishes to appoint a fully qualified Chartered Mechanical Engineer with 5 to 10 years' experience in the design and development of precision mechanisms An applicant of sufficient calibre will be considered for the post of CHIEF MECHANICAL ENGINEER. A salary of up to £2000 per annum is envisaged and the usual staff amenities apply. Working conditions are good.—Applications, which will be held in absolute confidence, should be addressed for the personal attention of the Technical Director, Box TE.475, c/o Hanway House, Clark's Place, E.C.2.

E5440 A

SITUATIONS VACANT

ASSISTANT MECHANICAL ENGINEER

required for
NORTHERN NIGERIA

with general workshop experience and emphasis on basic machine tools.

Applicants should be able to operate quick-change machine lathe with taper attachment and also planer. Good oxygen and electric arc welding experience also desirable.

Vacancy is for junior post.

Three months paid leave after 18 months tour of duty.

Write Box TE.506, c/o Hanway House, Clark's Place, E.C.3.

E5513 A

BP has vacancies for young MECHANICAL ENGINEERS for service with its Overseas Exploration Drilling Operations. Applicants up to 30 years old, must have H.N.C. in Mechanical Engineering or 1st M.O.T. Certificate and have served a five-year apprenticeship with a diesel engine manufacturer or acquired experience on the operating and maintenance of diesel engines at sea. Experience in outside erection of diesel engine driven plant and maintenance of refrigeration equipment advantageous. Attractive salary, free passages out and home, free medical attention, good leave arrangements. Kit allowance : Pension Scheme.—Write, giving full particulars, quoting F.591, to Box 3295, c/o Hanway House, Clark's Place, E.C.2.

E5508 A

BRITISH OXYGEN GASES LIMITED

ELECTRICAL ENGINEER

An electrical Engineer between 25 and 30 years of age is required for interesting development work in connection with power units and control gear for inert gas welding. A knowledge of electronics is an advantage, and the candidate should possess a degree or H.N.C. in electrical engineering.

TECHNICAL ASSISTANT

Technical Assistants are also required in the age range 25-30. They should have an electrical background and a H.N.C. in electrical engineering would be preferred. Candidates should have a knowledge of electronics or development experience in industry.

There are good future prospects and very good commencing salaries are offered. Housing assistance is available if required. Please reply stating full particulars to the Personnel Manager, Spencer House, St. James's Place, London, S.W.1.

E5528 A

CLERK OF WORKS (TEMPORARY) required for supervision of contract for the construction of new locks and other works on the River Lee Navigation and at Regent's Canal Dock, Stepney. Must have experience in supervising large civil engineering contracts ; experience in mass concrete and steel sheet piling desirable. Salary £900 to £1000. Certain railway travel privilege facilities.—Apply in writing, giving full particulars, to : Divisional Staff Assistant, British Waterways, "Willow Grange," Church Road, Watford, Herts. Closing date : one week after the date of this advertisement.

E5511 A

CONSULTING ENGINEERS with large Overseas practice require RESIDENT ENGINEERS for work abroad. Applicants should be aged 25-35, possess as a minimum requirement H.N.C. and preferably membership of The Institution of Mechanical or Electrical Engineers. Experience of erection of steam power plant including welding techniques for mild steel and alloy piping an advantage. Candidates would be given a short period of training before proceeding Overseas. Salary and allowances commensurate with age and experience.—Applications to be addressed to Merz and McLellan (Ref. "RE"), Carliol House, Newcastle upon Tyne.

E5488 A

DESIGN DRAUGHTSMAN required to work on Marine Propulsion Gears. Vacancies at Westminster and also Chesham offices. Permanent, pensionable positions. Good salaries.—Apply in first instance in writing to Technical Manager, Modern Wheel Drive Ltd., Lindo Lodge, Chesham, Bucks.

E5391 A

DRAUGHTSMAN (Proposal) for interesting work on complete Water-Tube Boiler installations. Applicants should have some previous experience of Water-Tube Boiler construction and layout. Salary according to experience. Contributory Pension Fund. Staff dining room.—State (in writing), age and experience.—Staff Manager, Foster Wheeler Limited, 3, Ixworth Place, London, S.W.3.

E5425 A

DRAUGHTSMAN REQUIRED for Mechanical Engineering Company, Charlton District. Suitable candidate, preferably with H.N.C. or equivalent may be offered original development work.—BOX No. E2940, "The Engineer."

A

DRAUGHTMEN are required for interesting work on small electric motors of various conventional and novel designs in the drawing offices at our Islington and St. Albans factories. An apprenticeship or similar sound D.O. experience in mechanical engineering is required, electrical experience an advantage. Interviews in London or St. Albans.—Write in the first case to : Limit Engineering Group Ltd., 64 Essex Road, London, N.1.

E2930 A

EDWARD A. PITCHER & PARTNERS require experienced R.C. Designer/Draughtsmen. Commencing salary £1150 p.a. Progressive positions with interesting projects. 5-day week. Luncheon Vouchers.—Apply : 14 Queenhithe, E.C.4.

E5529 A

ESTIMATOR for Fabrication, Plate Work, Pressure Vessels, Welded Structures, etc., required for East Anglia. State experience and salary required. BOX No. E2958, "The Engineer."

A

SITUATIONS VACANT

ENGINEERING ASSISTANT

£1400 p.a. is the minimum a graduate with an engineering degree (mechanical preferred) is expected to command if he has the qualifications and experience we are seeking. The successful candidate will have supervisory experience over technical staff and some experience of process electronic instrumentation. Experience of mechanical/electronic development work is preferred. A theoretic knowledge of electronics near degree standard and knowledge of electrical engineering, pneumatic control systems and drawing office practice is desirable. He will be based in London and assist the Chief Engineer in the protection and maintenance of all grounds, buildings, plant and services used by the Company. His responsibilities will include the design and procurement and installation of machinery and ancillary equipment in our factories. Applications giving full details of experience, qualifications and present salary should be sent in confidence to Personnel Manager, BOX No. E2957, "The Engineer." A

GIRL capable of tracing work (typing an advantage but not essential) required by a City Insurance Firm. Salary according to ability. Luncheon vouchers. 5 day week. Permanent progressive post. BOX No. E5530, "The Engineer." A

HIGHLY QUALIFIED ENGINEER required by major cycle manufacturers in India. Must have had practical experience in latest production techniques and operation of automats. Excellent salary and home leave arrangements : free furnished house and other facilities. This is an unusual opportunity for an executive engineer capable of adapting himself to local conditions, who possesses drive and initiative as well as experience and who is seeking a permanent career in Asia. BOX No. E5418, "The Engineer." A

IMPORTERS REQUIRE REPRESENTATIVES already calling on Engineering Concerns to carry Welding Cutting Equipment and Machine Tools.—BOX No. E191, "The Engineer." A

JUNIOR MECHANICAL DRAUGHTSMEN having completed National Service, required for work on large chemical plant installations. A.E.S.D. minimum rates or above. Five-day week and superannuation scheme. Replies giving details of age, qualifications and experience and quoting ref. LCL/TE1/54, should be addressed to Drawing Office Superintendent, LAPORTE CHEMICALS LIMITED, Oyez House, Fetter Lane, London, E.C.4. E5500 A

LIFT ENGINEER required by Insurance Company for inspection of lifts. Must have served apprenticeship with lift construction firm and hold at least O.N.C. or equivalent in Electrical or Mechanical engineering. London. Starting salary £800 p.a, pension, widows pension, etc.—Write with full details to Box E697, LPE, Romano House, 399-401, Strand, W.C.2. E5507 A

MECHANICAL ENGINEER DESIGNER. Civil Engineering Contractors specialising in foundations require good practical man for design and development work. The Company builds the majority of its own plant at its St. Albans Depot where the successful candidate will be based. He will take charge of a small Drawing Office, supervise construction of his own designs and visit contract sites when necessary. Housing accommodation is available if required, and a contributory Pension Scheme is operated by the firm.—Apply in writing, giving details of experience and salary required to : Frankipile Limited, Hatfield Road, St. Albans, Herts. E2945 A

LONDON TRANSPORT require a TEMPORARY EXECUTIVE ASSISTANT in the Permanent Way Department, Lillie Bridge.

The duties of the post consist of detailed planning, estimating and execution of permanent way work. A comprehensive knowledge of permanent way equipment and processes is necessary and experience in the control of staff would be an advantage.

Commencing salary : £1070 per annum.

Free Travel : Medical examination.

Applications to Staff and Welfare Officer, LONDON TRANSPORT EXECUTIVE, 55, Broadway, S.W.1, quoting reference 103/2. E5476 A

SENIOR MATERIAL HANDLING AND STRUCTURAL ENGINEERING DRAUGHTSMEN, age 25 to 35, required for Design and Detail Work in our Bromley, Kent, and Brighton offices. Salaries over A.E.S.D. rate, commensurate with ability and experience. 37½-hour week, 3 weeks annual holiday (one week granted this year.—Write, stating age and details of experience to John Wilson and Co. (Engrs) Ltd., 30, Widmore Road, Bromley, Kent. E2943 A

THE BEECHAM GROUP

has a vacancy

for a SENIOR CHEMICAL ENGINEER (30/40) with experience in Chemical Plant Design and Operation and a sound engineering background. Experience in refining or fermentation an advantage but not essential.

This is a senior appointment and carries a commensurate salary.

Profit Participation and non-contributory Pension schemes are in operation.

Applications in writing only, giving full details of age, qualifications and experience, and quoting reference SCE 84, should be forwarded to the Personnel Controller, Beecham Group Limited, Beecham House, Great West Road, Brentford, Middlesex. E5520 A

TECHNICAL DIRECTOR is required by a progressive medium-sized general engineering Company in Glasgow. Applicants, who should have a civil or mechanical engineering degree and proven success, must be fully capable of taking complete charge of the technical departments involving Design, Research and Development and Drawing Office, new plant, &c., and should have had a good experience of works practice and modern techniques involved in welded fabrication units.

Corporate membership of a senior engineering institution would be an advantage to the candidates.

Candidates should be in the age range of 35-45. The post which carries a salary of £2000–£3000 according to experience, is a progressive one and there are pension, life assurance and personal accident schemes.

The work will be varied and interesting involving a wide range of products, including new products requiring urgent development and every encouragement will be given to man with competence, drive and enthusiasm. Foreign travel will be necessary from time to time.

Full details, which must include age, education, qualifications, previous and present posts, and stating present salary to Managing Director, BOX No. E2953, "The Engineer." These will be treated in complete confidence. A

THE BEECHAM GROUP

has a vacancy

for a qualified SENIOR ELECTRICAL ENGINEER in WORTHING. The successful candidate will be responsible for the operation and maintenance of electrical equipment including high and low voltage sub-stations, switch gear, etc. and process instrumentation. Experience with a supply authority or large electrical manufacturing organisation would be an advantage.

Profit Participation and non-contributory Pension schemes are in operation.

Applications in writing only, giving full details of age, qualifications and experience, and quoting reference SEE 83, should be forwarded to the Personnel Controller, Beecham Group Limited, Beecham House, Great West Road, Brentford, Middlesex. E5519 A

WESTERN REGION OF BRITISH RAILWAYS require :

ENGINEERING ASSISTANTS capable of supervising Drawing Office Staff and TECHNICAL ASSISTANTS experienced in the design of reinforced concrete and steel bridges and other structures to fill vacancies in posts in the salary ranges £1095–£1150, £990–£1034, and £875–£948 respectively.

Superannuation Fund. Reduced rates of travel and other concessions. Five-day week.

Applications, giving qualifications, age, and experience to :

Chief Civil Engineer,
British Railways,
Western Region,
Paddington Station,
London, W.2. E5475 A

WORKS MANAGER required for Agricultural Engineering Works in East Anglia. Must have knowledge of Batch Production of Machines and Management of Men. Staff now about 40. Housing accomodation available. Salary according to qualifications and experience.—Reply in confidence giving Age, Qualifications and Experience to BOX No. E5467, "The Engineer." A

WORK STUDY

Young men, preferably with technical experience, are required by the manufacturers of "Corona" Soft Drinks, for training as Assistant Work Study Officers. On completion of training, they will be employed on projects at our numerous establishments. Applicants should be between the ages of 18 and 25, with either an O.N.C. or a suitable G.C.E.—Apply, in writing, to the Personnel Manager, Thomas & Evans Limited, Beecham House, Great West Road, Brentford, Middx. E2959 A

REED CORRUGATED CASES

have a vacancy for a

WORKS ENGINEER

at their Brentford branch

Applications are invited from engineers aged between 28 and 40, with a sound engineering apprenticeship and technical training, preferably to H.N.C. level. This is a senior staff appointment and the successful applicant will be responsible to the Works Manager for mechanical, steam, electrical and building maintenance and internal transport. Excellent conditions of service are offered including a non-contributory pension scheme. Salary will be commensurate with the high standard required.

Please apply in writing, stating age, qualifications, experience, present post and salary, to :

The Personnel Department, Reed Corrugated Cases Limited, Reed House, Kew Bridge, Brentford, Middlesex

quoting Reference WE/B E5527 A

SENIOR ESTIMATING ENGINEER

for Process Plant and Pipework Cost Estimating.

Applicants must have considerable estimating experience. This is a permanent and pensionable position offering great opportunities for advancement. 5 day week. Hours 9—5.

Apply : **Personnel Manager,**
AIR PRODUCTS (G.B.) LTD.
49/50 Poland Street,
London, W.1.
GERrard 0616

E5526 A

BICC

MECHANICAL ENGINEERING AND PLANT LAYOUT DRAUGHTSMAN

required, 25/35 years of age, with good engineering background. Experience in general cable making machinery detailing and/or cable factory plant and services layout, whilst not being essential, would be an advantage. Five day week. Excellent working conditions. Staff Superannuation Scheme in operation. Write, stating age, experience and qualifications, to :—

THE PERSONNEL OFFICER,
BRITISH INSULATED CALLENDER'S CABLES, LTD.,
ANCHOR WORKS, LEIGH, LANCS.
E5492 A

BOOKS and PUBLICATIONS

HMSO

Sites and Foundations

by A. D. M. PENMAN, M.Sc., A.M.I.C.E.

Adequate site investigation is essential before a foundation can be laid and a building erected. This paper outlines the problems which may arise if soil conditions are not properly assessed. (Factory Building Studies No. 5) **3s.** (*post* 4*d.*)

Department of Scientific and Industrial Research

Report of the Research Council for the year 1959. (Cmnd. 1049) **4s. 6d.** (*post* 4*d.*)

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ENGLISH ELECTRIC

(WHETSTONE Nr. Leicester)

require a

HEATING AND VENTILATING ENGINEER

The successful applicant will be in the age group 25-35 and will have had several years' industrial heating experience. He will have a knowledge of high pressure hot water systems and the problems associated with testing of small turbines supplied from high pressure water tube boilers.

He should also be able to make recommendations for general improvements in heating and building insulation, and have a sound knowledge of ventilating and dust extraction methods.

The appointment is permanent and pensionable and assistance will be given with initial accommodation if necessary.

Enquiries, which will be treated in confidence, should give details of experience, qualifications and current salary and be addressed to the Technical Staff Officer, Dept. G.P.S., Marconi House, Strand, London, W.C.2., quoting reference E1917J. E5484 A

Classified Advts. continued on page 92

SITUATIONS VACANT

REED BROTHERS (ENGINEERING) LTD.

SENIOR and JUNIOR DRAUGHTSMEN required for varied and interesting design work on Medium and Heavy Hydraulic Press Projects.

Experienced men preferred, but applicants with good general engineering background considered.

Excellent working conditions with Pension Scheme and Luncheon Vouchers.

Replant Works,

Woolwich Industrial Estate,

London, S.E.18.

E5477 A

DRAUGHTSMEN

Draughtsmen are required at the Midlands Research Station, Solihull.

The duties are interesting and will include work on the design of pilot and prototype plant associated with the development of new high-pressure processes for the production of town gas.

Candidates should possess at least an O.N.C. certificate in Mechanical Engineering.

The salary for the appointments, which are pensionable and subject to medical examination will be within the range of £733-£927 per annum.

Applications, stating age, education and experience, should be addressed to the Industrial Relations Officer,

WEST MIDLANDS GAS BOARD

6, Augustus Road, Edgbaston, Birmingham, 15

E190 A

SITUATIONS VACANT

MSL *have been retained to advise on the appointment of a*

CRANE MANAGER

to lead the experienced technical and sales staff of a major heavy engineering group which proposes to establish itself as the foremost manufacturer of dockside and industrial cranes. This is a new appointment.

With a technical staff of over 60 he will control all contracts from enquiry to erection.

Candidates must be professional mechanical, structural or electrical engineers with a comprehensive knowledge of crane design and manufacture. They may already be deputy to the managing director of a crane manufacturer or Chief Engineer in the Dock and Harbour Board.

Preferred age 40 to 45 years. Initial salary not less than £3,500 with pension, life insurance and car. Please send brief details in confidence, quoting reference G.2542, to J. G. Smith. In no circumstances will a candidate's identity be disclosed to our client unless he gives permission after a confidential interview at which he will be given full details of the appointment.

MANAGEMENT SELECTION LIMITED

17, Stratton Street, London, W.1.

E134 A

SITUATIONS VACANT

A SENIOR ENGINEER

required by

THE ATOMIC WEAPONS RESEARCH ESTABLISHMENT, WOOLWICH COMMON, LONDON, S.E.18

To LEAD AND DIRECT A TEAM engaged in the inspection and functional testing of a wide variety of electro-mechanical equipment and to assist and advise on the development of test gear and ancillary laboratory equipment.

Applicants should have served a recognised apprenticeship or have had equivalent training and be Corporate Members of the Institution of Electrical Engineers. They should also have had a wide experience of electronic systems and their design, and be conversant with electronic measurement techniques. Some knowledge of production methods is desirable and previous experience of working with Government Inspectorates would be an advantage.

SALARY:— £1955 — £2255 p.a. including London allowance.

Superannuation Scheme. Generous Leave allowance.

For application form send postcard (or letter) to the Senior Recruitment Officer, A.W.R.E., Aldermaston, Berkshire, quoting Ref. 2739/25.

E5474A

THERMONUCLEAR DEVELOPMENT

PROFESSIONAL ELECTRICAL ENGINEER

required at

ATOMIC ENERGY RESEARCH ESTABLISHMENT, HARWELL

The appointment, which is a responsible one, embraces a wide field of interest including

- HIGH MAGNETIC FIELDS
- ELECTRICAL STRESS PROBLEMS
- ENERGY STORES AND HIGH VOLTAGE SUPPLIES

The work involves HIGH VACUUM TECHNOLOGY, HEAT TRANSFER and MATERIALS and EQUIPMENT SELECTION.

It is desired to solve certain physics problems before a major experiment is completed. Initially the successful applicant will act as Deputy Leader of a team engaged in the DESIGN DEVELOPMENT and COMMISSIONING of a functional scale model to solve these problems.

The work is of a fundamental nature and an Engineering Honours degree with relevant Post Graduate experience is desirable.

Salary within the range of £1370 — £1825 depending on experience and qualifications.

Housing and contributory Pension scheme.

Send Post Card for application form to Personnel Manager (1760/25), U.K.A.E.A., A.E.R.E., Harwell, Didcot, Berks.

E5479A

ICI

METALS DIVISION

An

ELECTRICAL APPLICATIONS ENGINEER

is required for the Division Engineering Department of Imperial Chemical Industries Limited at WITTON, near Birmingham.

Responsibilities include the design, application and co-ordination of electrical installations in a variety of plants.

Candidates, preferably in the age range 30/35, with corporate membership of the Institution of Electrical Engineers, should have a degree in electrical engineering and wide experience in heavy electrical engineering, including the application and layout of electrical equipment, switchgear and control equipment.

This appointment is pensionable and the Company operates a Profit-Sharing Scheme. Assistance can be given towards house purchase and removal expenses for married men.

Please write for an application form to the Assistant Personnel Manager (Staff), IMPERIAL CHEMICAL INDUSTRIES, LIMITED, Metals Division, P.O. Box 216, Kynoch Works, WITTON, Birmingham 6, quoting Eng/439/E.

E5481 A

ENGLISH ELECTRIC

RUGBY

require an experienced

DIESEL ENGINE DESIGNER

Applicants should have a graduate technical background and have considerable experience on the design of diesel engines preferably in the heavy range. A knowledge of Turbo-blowing applications would also be an advantage.

Write giving full details to Dept. G.P.S., Marconi House, Strand, London, W.C.2. quoting reference E 1104J.

E5485 A

ASSISTANT INSTRUMENT ENGINEER
ASSISTANT ELECTRICAL ENGINEER
AND ASSISTANT MECHANICAL ENGINEER

are required by the

UNITED KINGDOM ATOMIC ENERGY AUTHORITY at WINDSCALE AND CALDER WORKS, CUMBERLAND.

The Instruments and Electrical posts are associated with the new "Advanced Gas Cooled Reactor," now being built at Windscale, which will be operated at higher temperatures and ratings and is the experimental prototype for the next generation of nuclear power stations.

The duties of the Assistant Instrument Engineer will be to assist in the commissioning and maintenance of particle and radiation detectors, data loggers, closed circuit television, auto-control as well as pressure, temperature and flow measuring devices. This is an excellent opportunity for an engineer or physicist with experience in one or more of these fields to broaden his knowledge.

The Assistant Electrical Engineer will assist in a section providing an engineering service to the reactor, its associated auxiliaries and generating plant. A desire to work on the problems associated with a prototype reactor is an essential requirement.

The Mechanical Post will be to assist in the maintenance of mechanical equipment associated with Calder Hall Nuclear Power Station. This will include responsibility under a Mechanical Engineer, for the maintenance of sections of the plant, and for special investigations.

Applicants must have served a recognised engineering apprenticeship, pupilage, or have had comparable training, and be at least graduate members of an appropriate senior engineering institution, or equivalent.

Salary according to qualifications and experience within the scale £860 at age 25 to £1340 p.a. Contributory Superannuation. Staff Housing Scheme.

Send postcard for application form, quoting reference P/W.34/J1, to Recruitment Officer, U.K.A.E.A., Production Group, Windscale Works, Sellafield, Seascale, Cumberland.

Closing date: 15th August, 1960

E5480 A

SITUATIONS VACANT

St. Bernard's Hospital, Southall, Middlesex

Applications are invited for the post of

SENIOR ENGINEER

to assist Superintendent Engineer at large mental hospital (2,500 beds). Salary £845 p.a. — £1000 p.a. Whitley Council conditions of service.

A Ministry of Transport and Civil Aviation First Class Certificate of Competency in Marine Engineering or a Ministry of Transport and Civil Aviation Certificate of Service as a First Class Engineer or a City and Guilds full Technological Certificate in Plant Engineering (First Class) or an equivalent qualification is required.

Successful candidate will be required to reside within travelling distance of the hospital. Applications giving full particulars of age, qualifications and experience and the names and addresses of referees to the Group Secretary within two weeks of the appearance of this advertisement.

E5501 A

SITUATIONS VACANT

Works Engineers

Vacancies exist in the Works Engineer's Department of a large Company in East London for personnel capable of drawing, planning and estimating layouts for both machine and assembly shops from information supplied by time study departments, also experience in ventilation and extraction systems, palletisation and mechanical handling of stores, etc. Age between 30 and 40. A salary of up to £1000 per annum will be paid to the selected candidates. Please write, giving details of experience to BOX No. E5493, "The Engineer."

A

SITUATIONS VACANT

MECHANICAL DESIGN ENGINEER

Applications are invited by Davy and United Engineering Company Limited for the above position.—

The successful applicant should have the H.N.C. or equivalent in Mechanical Engineering and be experienced in the mechanical design of heavy rolling mill plant.

Good conditions, contributory pension scheme. Applications with details of qualifications and experience in confidence should be addressed to:—

Staff Personnel Officer
Davy and United Engineering Company Limited,
Darnall Works, Sheffield 9.

E5499 A

TECHNICAL DESIGNER
REQUIRED

Qualifications: Associate Membership Senior Engineering Institute or equivalent. Experience in heat transfer in the chemical engineering industry. Age 26-30.

WATER TREATMENT ENGINEER
REQUIRED

With experience in water filtration and treatment.

Please write giving details of experience and salary required to:

The Secretary,

Caird & Rayner LTD

777, COMMERCIAL ROAD, LONDON, E.14

E5504 A

PROJECT MANAGER

Applications are invited from holders of a degree or its equivalent in Chemical or Mechanical Engineering. Applicants must have considerable experience in project engineering in the chemical process or allied industries.

PROJECT ENGINEERS

Qualified engineers are also required to fill vacancies which exist in our rapidly expanding company.

Air Products (G.B.) Ltd. is engaged in the design, manufacture and erection of industrial gas plant. We have doubled our staff in the past 2 years and expect to continue this expansion. Great opportunities therefore exist for the ambitious engineer. These are permanent and pensionable positions at our London Offices — hours 9 to 5.

Apply: Personnel Manager,
AIR PRODUCTS (G.B.) LTD.,
St. Giles House,
40/50, Poland Street, W.1.

E5514 A

ENGLISH ELECTRIC

RUGBY

require

STEAM TURBINE DRAUGHTSMEN

The Company has many vacancies at present and would welcome applications from men with the following experience:-

STEAM TURBINE DETAIL DESIGN including knowledge of casings, shafts, blading, diaphragms, bearings etc.

POWER STATION & GENERAL LAYOUT WORK where a knowledge of pipework connected with high pressure steam and lubrication oil would be an advantage.

CONDENSER AND FEEDHEATER details and layout work.

These vacancies offer good prospects of permanent employment and advancement and are due to a further expansion of the Company's activities in the power generation field. Suitable recruits will be considered for Company houses or Flats.

Write giving full particulars to

G.P.S., Marconi House, 336/7 Strand, London, W.C.2.,

quoting reference E1199C.

E5483 A

ICI

ENGINEERS PHYSICISTS

The Fibres Division of Imperial Chemical Industries Limited

has openings for men to work in Research Department at Harrogate as

TEXTILE ENGINEERS

These openings will appeal to applied physicists—they will also be of interest to young graduate engineers who would prefer to start their industrial career in research and development and possibly transfer to general technical management in a few years time.

These men will become members of the existing teams which at present mainly consist of chemists and physicists working on the invention and development of new processes for making melt-spinnable synthetic fibres.

These vacancies are additional to the normal requirements for engineers in the Company.

Previous experience in the textile machinery industry is not essential—experience in the aircraft, motor car, guided missile or atomic energy industries might well enable applicants to bring new techniques to this field.

Conditions include five-day week, canteen facilities. Staff Pension Fund and Employees Profit Sharing. Assistance to married men to enable them to move into the district is available in the form of mortgage facilities, removal expenses and lodging allowances.

Write in the first instance to :—

The Personnel Manager,
Imperial Chemical Industries Limited
Fibres Division, Harrogate, Yorkshire
quoting Reference T.14/E.

E5468 A

Classified Advts. continued on page 94

SITUATIONS VACANT

POWER RECTIFIER DESIGN

Due to expanding business, a large electrical manufacturing firm in the Midlands requires assistant Design Engineers and Technical Assistants, for power rectifier work. Previous rectifier experience not necessary, but applicants should have degree (electrical), or HNC, or respective equivalents, and some practical training. Work involves mercury arc and semi-conductor rectifiers, and application engineering of all kinds, with scope for wide experience and interest; good salary and prospects. Pleasant residential area; ample housing; excellent educational facilities.

Apply with full particulars to BOX No. E5518, "The Engineer."

E5518 A

SALES ENGINEERS

Continued expansion and promotion within the Organisation has created a number of vacancies in the Field Force of a Leading Machine Tool Importing and Merchanting Company.

It is intended to make Senior appointments in North West (Lancs and Cheshire) and South West England (including West London and Home Counties). Junior posts are vacant in the North West (Yorkshire and Cheshire), and Midland Territories.

Only experienced, well-connected Machine Tool Sales Engineers with first-class record can be considered for Senior Appointments. Junio r men must be Apprenticed Engineers up to 30 years of age with sound knowledge of heavy duty machine tools and preferably some selling experience.

Remuneration will be by salary, commission and expenses.

Apply with full details in confidence to Sales Manager, BOX No. E5495, "The Engineer."

A

APPLEBY-FRODINGHAM STEEL COMPANY

SCUNTHORPE - LINCOLNSHIRE

invite applications for

SENIOR DESIGNER

also

SENIOR and JUNIOR DRAUGHTSMEN

for general engineering work.

Experience with plant for Iron and Steelworks would be an advantage but is not essential.

Permanent situations with good prospects of advancement for men with initiative and ability.

Staff Pension Scheme, welfare and sports facilities are available.

Apply, giving age, full particulars of previous experience and technical qualifications to the Chief Engineer. E5491 A

SITUATIONS WANTED

A.M.I.MECH.E. (48), English, wide experience home and overseas, plant, maintenance, production, ship repairs. Middle or Far East preferred but not essential.—BOX No. E2954, "The Engineer." B

REPRESENTATION — SOUTHERN AFRICA. Engineering Executive, 40, A.M.I.Mech.E. and Union Govt. Mining Engineers Certificate, resident in Johannesburg since arrival from U.K. in 1948, with sound practical experience of manufacturing, administration and selling, principally in the machine tool, automotive and contracting plant industries, seeks full time appointment as S.A. representative of reputable Company, or similar post.—Box 9430 Johannesburg. E5502 B

SUB-CONTRACTING

KELLERING AND CAM PROFILING capacity up to 8ft by 6ft or 6ft diameter.—ARMYTAGE BROS. (KNOTTINGLEY), Ltd., The Foundry, Knottingley, Yorkshire (Telephone: Knottingley 2743/4). E116 MW

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A BARGAIN. £25 complete. BRAND NEW READY-MADE CO. REGNS. Guaranteed no trading (ENGLAND OR SCOTLAND)—all trades available NOW, including Engineering; Electrical Engineering; Motor Engineering; Garage; Machinery; Metal; Haulage; Hire Purchase; Investment; Property (specially prepared for each trade).—BUSINESS ECONOMY CO. REGNS., LTD., Dept. T/16, 156, Strand, London, W.C.2. (Tem. 8377/2294), for English companies, and to 19, Walker Street, Edinburgh, 3 (Cal. 1167/8/9), for Scottish Companies. Read "ADVANTAGES OF TRADING AS A LIMITED COMPANY" (3s. post free); Limited Co. may save you tax. We have seven-day Co. Regn. service with your own choice of name. £21 complete, plus stamp duties. E182 O

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MOBILE LIFTING SERVICE. Lump Sum or Hire Rate quoted for any lifting work by Lorry-Mounted or Crawler Cranes, any size, any area.—TARSLAG, LTD., Rotherham 78481. E186 K

PATENTS

THE PROPRIETOR of British Patent No. 709958, entitled "IMPROVED PLUG CLOSURES FOR HAND AND LIKE HOLES IN PRESSURE VESSELS" offers same for license or otherwise to ensure practical working in Great Britain.—Inquiries to Singer, Stern and Carlberg, 140 S. Dearborn Street, Chicago 3, Illinois, U.S.A. E5422 H

THE APPLICANT for United Kingdom Patent Application No. 25578 of 1956 entitled "IMPROVEMENTS IN OR RELATING TO ROTARY ENGINES OR PUMPS" is anxious to contact a firm or individual willing to exploit this invention which relates particularly to a slow-acting turbine.—Enquiries to G. F. Redfern and Co., Redfern House, Dominion Street, London, E.C.2. E5471 H

THE PROPRIETORS OF BRITISH PATENT NO. 764159 relating to "ROLLER COUPLINGS" offer same for license or otherwise to ensure practical working in Great Britain.—Enquiries to Frank B. Dehn and Co., 103, Kingsway, London, W.C.2. E5489 H

DRAWING & DESIGN SERVICE

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STAFF ARE SECURITY CLEARED FOR WORK ON GOVERNMENT SITES INCLUDING SHIPS.

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MACHINERY Etc. WANTED

SOME USED DIESEL ENGINES. Dorman Power Unit, type DL4 or DL6.—Send full details and price to Box 5086, Grijseels Advertising—166 Nieuwe Binnenweg-Rotterdam-Holland. E5512F

MISCELLANEOUS

DAVIES INVESTMENTS LIMITED

BANKERS

(Gross assets £2,000,000), are paying 7½ per cent. p.a. interest on deposits for the seventh year in succession, with ½ per cent. added annually on each £500 unit.—Details and Audited Balance Sheet from: Investment Dept. ER,

DAVIES INVESTMENTS LTD., DANES INN HOUSE, 265 STRAND, LONDON, W.C.2.

E178 I

FOR SALE

FRED WATKINS (ENGINEERING) LTD.

STEAM BOILERS.—Cochran Vertical (New) 7ft. and 6ft. 6in. dia., 150 lb. w.p.; reconditioned 9ft. down to 3ft. dia.; Economic 4ft. to 11ft. 6in. dia., including new 8ft. dia., 150, 180 and 200 lb. w.p.; 300 reconditioned Vertical Crosstubes, all sizes.
AIR COMPRESSORS.—Two Belliss & Morcom 2500 c.f.m., 100 p.s.i., 550 h.p. motors; also Broomwade 500, 400, 300, 200 and 130 c.f.m., all motorised; and several others of various makes and capacities.
200 AIR RECEIVERS, stocked up to 9ft. dia., 100 to 500 lb. pressure.
ELECTRIC MOTORS.—150 Totally Enclosed and Flameproof Motors up to 200 h.p.
MOBILE ROAD CRANES.—10-ton Lorain lorry-mounted 30ft.-70ft. extendible jib; 8½-ton Ransome Diesel/Electric 21ft. jib; 6-ton Coles Diesel/Electric, solids; 4-ton Soles Diesel/Electric, solids, 1945; 4-ton Jones KL44, diesel, 1950; 3-ton Jones "Super 40" diesel, pneumatics (3).
OVERHEAD CRANES.—25-ton Girders and end carriages, with 60 h.p. motors, 95ft. 10in. span; 30-ton Vaughan, 42ft. 3in. span; 25-ton Clyde, 21ft. 9in. span, new 1954; 20-ton Vaughan, 42ft. 3in. span, 6-ton auxilliary, cab control (5); 20-ton King, 42ft. 3in. span, 400/3/50; Wharton, 7½-ton, 25ft. span, 400/3/50; 5-ton Henderson, 24ft. 7in. span 1946; 5-ton Morris, 58ft. span, hand-operated; 5-ton King, 29ft. 3in. span, power hoist, hand travel; 5-ton Morris, 28ft. 6in. span, power hoist, hand travel; 4-ton Morris, 19ft. span, 220V. d.c. (3); majority of the above are unused.
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		Main Location	*Auctioneers*
August 16-17	Miscellaneous stores, including :—	M.O.A. Storage Depot, Ruddington, Notts.	WALKER, WALTON & HANSON (Dept. L), Byard Lane, Bridlesmith Gate, Nottingham. (Tel.: 54272.)
	A Crabtree rotary printing press ; lathes ; drilling and milling machines ; grinding machines ; polishing heads ; machine tool spares ; air compressors ; petrol cans ; starter motors ; generators ; dynamos ; fire extinguishers ; battery charging sets ; batteries ; M.T. spares ; tubes ; flaps ; tyres ; hydraulic and screw jacks ; electrical spares ; metal shelving and binning ; wooden levers and benches ; canvas covers ; canopies and side curtains ; embroidery canvas and wool ; cotton ; fasteners ; pins ; haversacks ; clothing ; bedding ; furniture ; canteen and hostel equipment, etc.		
August 23	Miscellaneous stores.	Central Ordnance Depot, Didcot, Berks.	SIMMONS & SONS (Dept. L), 12, Station Road, Reading, Berks. (Tel.: 54025.)
September 1	Vehicles, machine tools and miscellaneous stores.	M.O.A. Storage Depot, Bowhouse, Hurlford, Nr. Kilmarnock, Ayrshire.	DIXON & WALLACE, LTD: (Dept. L), Bank Buildings, Graham Square, Glasgow, E.1. (Tel.: Bridgeton 2447/9.)
September 6-7	Machine tools and miscellaneous stores.	M.O.A. Storage Depot, Royal Arsenal, Woolwich, London, S.E.18.	FULLER, HORSEY, SONS & CASSELL (Dept. L), 10, Lloyd's Avenue, London, E.C.3. (Tel.: Royal 4861.)
September 13	Miscellaneous stores.	No. 1 E.S.D., Long Marston, Nr. Stratford-on-Avon, Warwicks. (Sale at the Hippodrome, Stratford-onAvon.)	LOCKE & ENGLAND (Dept. L), 166, Parade Leamington Spa, Warwicks. (Tel.: 2833.)
September 16	Miscellaneous stores.	M.O.A. Storage Depot, Rotherwas, Hereford.	RUSSELL, BALDWIN & BRIGHT, LTD. (Dept. L), 20, King Street, (Tel.: 4366.)
September 21	Machine tools and miscellaneous stores.	Technical Stores Depot, Old Dalby, Leics. (Sale at Melton Mowbray.)	SHOULER & SON (Dept. L), 1, Norman Street, Melton Mowbray, Leics. (Tel.: 3081.)
September 23-30	Vehicles, motor cycles, earth moving and lifting equipment.	M.O.A. Storage Depot, Ruddington, Notts.	WALKER, WALTON & HANSON (Dept. L), Byard Lane, Bridlesmith Gate, Nottingham. (Tel.: 54272.)

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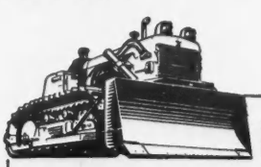

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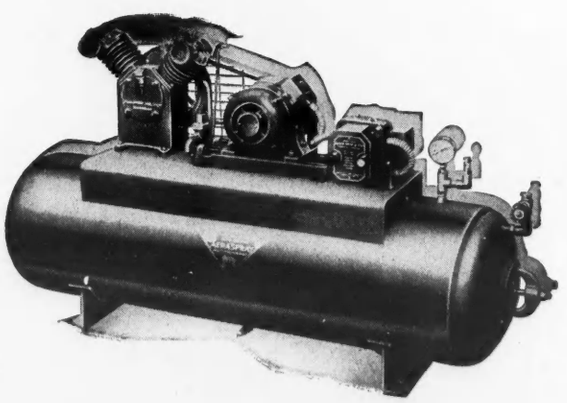

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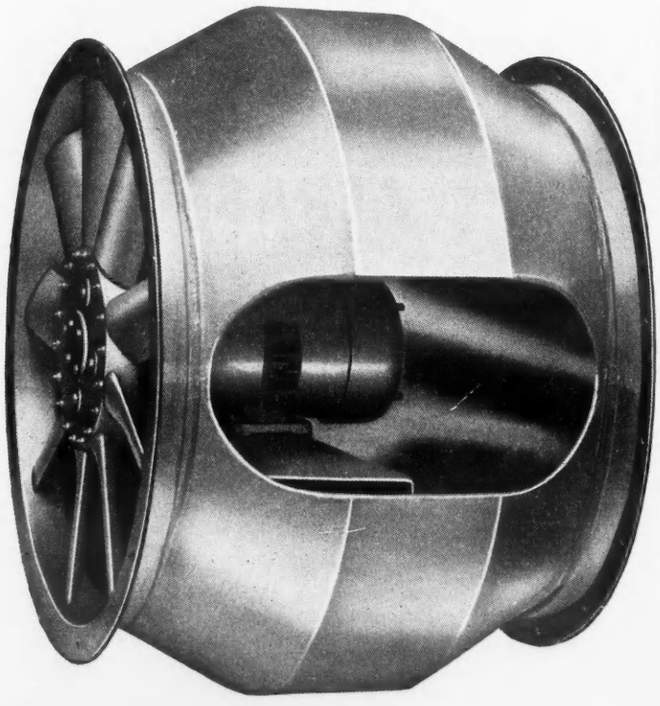

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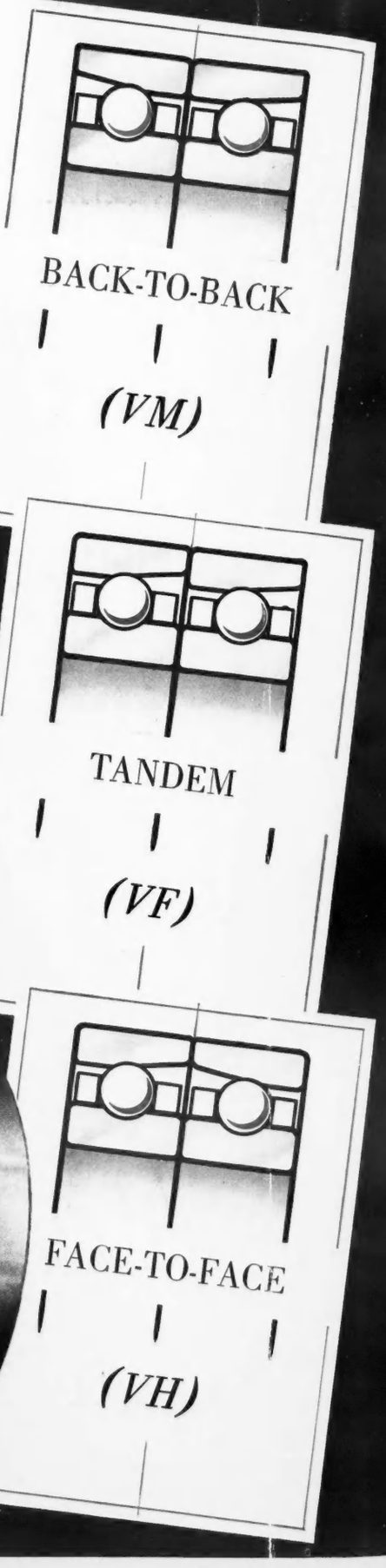

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